

The Impact of Integrated Programming on Student Attitude and Achievement in  
Grade 9 Academic Mathematics and Science

Cindy Cosentino, B.Sc. (Hons), B.Ed.

Department of Graduate and Undergraduate  
Studies in Education

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Faculty of Education, Brock University  
St Catharines, Ontario

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## **Abstract**

This research studied the effect of integrated instruction in mathematics and science on student achievement in and attitude towards both mathematics and science. A group of grade 9 academic students received instruction in both science and mathematics in an integrated program specifically developed for the purposes of the research. This group was compared to a control group that had received science and mathematics instruction in a traditional, nonintegrated program. The findings showed that in all measures of attitude, there was no significant difference between the students who participated in the integrated science and mathematics program and those who participated in a traditional science and mathematics program. The findings also revealed that integration did improve achievement on some of the measures used. The performance on mathematics open-ended problem-solving tasks improved after participation in the integrated program, suggesting that the integrated students were better able to apply their understanding of mathematics in a real-life context. The performance on the final science exam was also improved for the integrated group. Improvement was not noted on the other measures, which included EQAO scores and laboratory practical tasks. These results raise the issue of the suitability of the instruments used to gauge both achievement and attitude. The accuracy and suitability of traditional measures of achievement are considered. It is argued that they should not necessarily be used as the measure of the value of integrated instruction in a science and mathematics classroom.

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## **CHAPTER ONE: THE PROBLEM**

Look around on a typical workday and notice what people are doing. On the highway a police officer is seen making accurate measurements of skid marks at the scene of an accident to analyze exactly what happened. In line at the local deli, a food handler is observed monitoring and tracking the temperature of cooked food to ensure it remains within a safe range. In the field beside a paint factory an environmentalist is collecting data to determine whether native plant species are at risk from local pollution. A renovator is deciding whether a support beam will be needed if a wall in the house is going to be knocked down to make way for a kitchen renovation. The family doctor is jotting figures on a prescription pad, calculating the safe dosage of a drug for a young child. In order to be carried out in a thoughtful manner, all of these varied workplace experiences draw upon the understanding and simultaneous application of both science and mathematics. In the day-to-day activities of many people the two disciplines are closely intertwined. It is not often that one finds one without the other.

Consider now a typical secondary school. Observe the students in the mathematics classroom, learning the concepts and applying the skills that are required to be considered competent in mathematics. Down the hall and in the science lab the same students will perform experiments and learn all the big ideas of biology, physics, and chemistry. Each discipline has its own classroom, its own teacher, and its own textbook. Rarely is one ever mentioned in the consideration or context of the other. Rarely are students required to employ both science and mathematics together in the authentic and effective manner that adults in the workforce do on a daily basis. The two disciplines, so closely married in practice, are usually kept far apart in the realm of the classroom. It is

little wonder that science and mathematics teachers hear that familiar refrain so many times: “What do we need this stuff for, anyways?”

Why are such natural partners kept separate in schools, especially at the secondary school level? This research explores the implications of combining science and mathematics instruction at the secondary school level. The purpose of this study was to determine the impact of an integrated science and mathematics curriculum on grade 9 academic students. Although academic achievement in science and mathematics is a significant indicator of student success, this research also aims to determine whether any attitudinal changes toward either subject area were noted as a result of the integration. How were the students affected with this approach to science and mathematics instruction?

### **Background to the Problem**

How well students do in science and mathematics has for a long time been a politically and socially significant issue. In most developed countries the achievement of students in these two areas is seen as a measure of the success of the society and a predictor of the ability to compete in the international marketplace (Black & Atkin, 1996). Students are thought to need a solid understanding of scientific facts and figures and to have excellent mathematics skills while at the same time being dynamic and creative problem solvers who are able to apply their mathematical and scientific understanding in a diverse and ever-changing world. Science and mathematics are seen as the critical pathways to success in life. When students experience limited success or enthusiasm for either subject, it is likely that they will have fewer choices and reduced potential for optimal participation in the employment market (Walters, 2004). Canada has

performed well on recent international testing. The 2003 Programme for International Student Assessment (PISA) ranked Canadian 15-year-olds third in mathematics and fifth in science (Council of Ministers of Education, Canada, 2003). However, according to the government report *Knowledge Matters* (Human Resources Development, Canada, 2002), if Canada hopes to meet “the economics and social challenges of the knowledge based economy, it is critical that all our children and youth have the opportunity to fulfill their learning potential” (p. 23). One of the means by which this can be accomplished, the report goes on to say, is by Canada becoming one of the top three countries in both science and mathematics. Performance in science and mathematics, then, is officially a national concern.

At the provincial level, the past 10 years have seen major upheaval and change in science and mathematics education. With the introduction of new curricula in science and mathematics in 1999 came an almost immediate cry of disapproval from major stakeholders. The curricula were thought to be overcrowded, unmanageable, and too demanding for the students. Alarm bells began to ring more loudly when it was determined, a few years into the changes, that many students simply were not earning the credits that were expected by the end of grade 9 and that this in turn was affecting the ultimate goal of their high school careers. According to King (2003), poor performance in grade 9 and 10 courses lead in turn to reduced credit accumulation and subsequently lower graduation rates. In May 2005, The Ontario Ministry of Education released revised curriculum documents for mathematics and is in the process of revising the science curriculum in a similar fashion.



In one Ontario school board, there are some indications that there is some room for improvement in the areas of science and mathematics achievement in grade 9.

According to the Director's Annual Report 2003-2004 for this Board of Education, only 51% of males and 55% of females were achieving a grade of 70% or better in their grade 9 compulsory academic mathematics credit. Science was better, but only marginally, with 58% of males and 65% of females meeting the provincial standard of achievement in academic science. According to the Ontario Ministry of Education, academic courses "develop students' knowledge and skills through the study of theory and abstract problems. These courses focus on the essential concepts of a subject and explore related concepts as well. They incorporate practical applications as appropriate" (Ministry of Education, Ontario, 2000, p. 4). Academic courses are required as prerequisites to enter university or college/university level courses in grades 11 and 12.

It is interesting to note that the mathematics grades were in contrast to relatively strong scores on the Education Quality and Accountability Office (EQAO) mathematics test. In 2003/2004, 68% of students in this board achieved the provincial standard or better. This suggests that there was some discrepancy among the teaching, the assessment and evaluation, or the standard of achievement against which students were being measured.

Attitude toward science and mathematics is an important indicator of achievement and will determine the number of courses in science and mathematics that students will ultimately take (Gilroy, 2002). It is possible to read attitude indirectly, though, through other measures. At one secondary school previously mentioned Board of Education, there are some observations that support the belief that students' attitudes towards science and

mathematics are not optimal. For instance, of the approximately 300 students entering grade 10 in the 2003/2004 school year, only about 30% continued on to take grade 11 university chemistry or biology. From there, only about 20% opted to then complete the grade 12 chemistry and 24% the grade 12 biology. Physics had even lower numbers with 17% taking the grade 11 university course and 9% continuing to grade 12.

Discouragingly smaller numbers had selected the college level science courses of chemistry (8%) and biology (7%), and so few selected the college level physics that it had been cancelled for the 2005/2006 school year. These numbers, taken from data provided by the Midtown guidance department, were approximate and could speak to only one class of students moving through the school. The data are consistent with previous years and suggest that science is not considered a serious choice for students when they specialize in their senior years. This is further supported by data for applications to colleges and universities made by the most recent graduating class. Of 531 individual applications to universities, a total of 126 or 24% were for fields directly related to science and mathematics. An examination of the data provided by the secondary school's guidance department shows that of 68 students attending community college after graduation, only 14 (35%) are heading into studies directly related to science or mathematics. Despite career and course counselling about the importance of science and mathematics education, students are heading down other pathways as they progress towards their ultimate career destination.

At all levels, nationally, provincially, at the school board level, and within the school itself, concerns exist about the quality and impact of science and mathematics

education. The effort to improve science and mathematics education is occurring, with varying degrees of intensity and success, at each of these levels.

### **Statement of the Problem Situation**

The purpose of this study was to investigate the impact of an integrated science and mathematics curriculum on the attitude and performance of grade 9 students. While previous research is inconclusive on the impact of such an integrated program, it has tended to focus strictly on traditional measures of academic success, which are not necessarily an accurate indication of how much learning actually occurred. Comparatively little research exists that examines attitudinal changes resulting from participation in such a program (Yager, 2000).

In order to address this research problem, the following questions were asked:

1. What impact does the participation in an integrated science and mathematics program have on student achievement in both science and mathematics?
2. How are the attitudes toward science and mathematics affected by participation of the students in the integrated program?

### **Rationale for the Problem**

Integration is frequently cited as a desirable approach to instruction without, as previously mentioned, necessarily having evidence to support the notion that it is preferable to traditional, segregated instruction (Meier, 1998). The idea of integrated instruction being better endures despite the paucity of evidence. There are very compelling arguments that can be made for the benefits of integration that imply positive effects on achievement and attitude. Such arguments include the relevance of an integrated program to students, the efficient use of time that integration could potentially

allow, and a refreshing possibility for change to assessment and evaluation that integration may offer (Drake, 1998). Of all the reasons for attempting integration, none is as compelling as the idea that it will catch the interest and ignite the enthusiasm of the adolescent learner through careful selection of relevant, real-world problems. As Beane (1991) suggests:

Given a pile of jigsaw puzzle pieces and told to put them together, no doubt we would ask to see the picture they make. It is the picture, after all, that gives meaning to the puzzle and assures us that the pieces fit together, that none are missing, and that there are no extras. Without the picture, we probably wouldn't want to bother with the puzzle....To students, the typical curriculum presents an endless array of facts and skills that are unconnected, fragmented, and disjointed. That they might be connected or lead towards some whole picture is a matter that must be taken on faith by young people. (p. 9)

Seeing a problem in a realistic, reasonable context can be seen as a benefit and can be seen to improve understanding and the application of knowledge by students (Venville & Wallace, 1998). Integration has the potential to eliminate that most dreaded of questions, the one that students invariably pose when they fail to see any connection between the material they are learning and their life now or in the future. This connection would become, in fact, self-evident (Berlin & White, 1994).

Coupled with increasing the relevance of science and mathematics for students is the subsequent improvement in attitude that may follow. Berlin and White (1994) felt that motivation to succeed was enhanced by experiences in an integrated science and mathematics program. Increases in confidence may help to change students' negative

perceptions about science and mathematics and assist students in perceiving science and mathematics as pursuits in which they are capable of participating fully. It stands to reason that successful participation in the solving of authentic, relevant problems will encourage a capacity for mathematical and scientific thought.

Time is a constantly short commodity in Ontario schools. As Lyngard (2004) noted in her examination of scheduling in Ontario secondary schools, teachers feel increased pressure to do more in a shorter timeframe. The pace of lessons has increased, and students have less time to reflect on, structure, and consolidate new understandings. By integrating science and mathematics, opportunities may be increased for the reflection and restructuring necessary for students to construct their learning. Similar expectations can be combined and assessment tasks can be created to capture the richness of both subject areas, rather than tackling each one separately. This will save time and open up the space in the planning to allow for increased opportunities for learning. Schmitt and Horton (2003) found that in their experience with interdisciplinary learning, they were able to build in multiple opportunities to revisit challenging mathematical concepts in different scientific contexts. Ross and Hogaboam-Gray (1996) state that “integration could also focus student attention on the most important ideas to learn. These essentials consist of outcomes that are shared by many subjects as well as those that are unique to a single discipline” (p. 1). Rather than setting students on a mission to collect “a disconnected and incoherent assortment of facts and skills” (Beane, 1995, p. 618) that are thought to be the end goal of education, it is better and more productive to focus attention on the overarching ideas that are most significant and that tie the facts and ideas together in a meaningful and significant way. If details are missed or fine points overlooked, as is

likely to happen in even the most traditional of classrooms, it is not at the expense of understanding the more important “big ideas.”

As Beane (1995) stated, “Curriculum integration is not about doing the same things differently but about doing something truly different” (p. 622). In integrating the two subjects, it may be possible to realize, with greater success, the intentions of assessment and evaluation as stated in the Ontario Program Planning and Assessment (Ministry of Education, Ontario, 2000) document. This document suggests that the primary purpose of assessment and evaluation is to improve student learning, and suggests that assessment and evaluation activities “are varied in nature, administered over a period of time, and designed to provide opportunities for students to demonstrate the full range of their learning” (p. 13). Despite this description, tests and exams are still the primary method used for evaluation in secondary schools. The impact of this approach is aptly described by Yager and Lutz (1994), who demonstrated how science students, selected for their excellent performance in science and mathematics, had a very difficult time solving real-world problems. Remarkably, excellent performance on traditional evaluation methods did not correlate with similarly excellent abilities to apply knowledge in a useful and meaningful way. If the goal of an integrated program is to improve student success, then looking for evidence of that success in the traditional places will not be sufficient. As Yager (2000) states, “Traditional tests are a poor indicator of whether an individual has actually learned something (p. 332). Wells (2004) described this movement away from testing in an integrated classroom with a resulting dramatic improvement in student success as learning was viewed with a broader definition and achievement measured in a greater variety of ways. The Ontario Program Planning and

Assessment (Ministry of Education, Ontario, 2000) document states that assessment and evaluation should be “appropriate for the learning activities used, the purposes of instruction, and the needs and experiences of the students” (p. 13). Although this should already be happening in every classroom, the nature of the well-integrated classroom will demand that it be so.

### **Scope and Limitations of the Study**

In order to set up an integrated science and mathematics program, many conditions contributed to the limitations in the study. The study required that the researcher design and implement the integrated curriculum and be the only person teaching the program in the first year. This may have led to effects not related to the integrated program but to the nature of the teacher and her classroom style and methodology. The students were required to have parent approval in order to be placed into the program. Although the students were randomly selected from the applicant list, the very act of requiring parent approval was selecting for a population that likely already had an existing bias in favour of science and mathematics education. Parental attitudes may have been significant in the impact they had on their children.

The students participating were only those enrolled in both academic (university preparation) science and mathematics, which again suggests a bias in favour of both subject areas. These students were possibly already considering careers in these fields and may have experienced success in grade 8 science and mathematics. Finally, the course was a full year, de-semestered course. This may have had a positive impact on achievement unrelated to integration compared to the rest of the population that was enrolled in a single semester of science and mathematics.

### **Importance of the Study**

This study is of importance on several different levels. To the researcher, it provides some resolution to a long-considered question concerning the effects of integrated programming. The results will guide and inform future decisions about how science and mathematics education are handled in her classroom and whether advocacy for such a program can be defended. The research may provide impetus for further expansion of integrated programming within the grade 9 year and into grade 10 at Midtown Secondary School. It also has initiated discussions about the possibilities of integration for applied level students.

The research will have an impact beyond the school and classroom. The data have been shared along with the program itself with the hope that other teachers and schools may be willing to try to integrate some part of their science and mathematics program. The program was presented at the Science Teachers' Association of Ontario Conference in November 2006 and will be presented again with a more comprehensive examination of the findings in 2007. In addition, it will be shared with teachers in the Suburban District School Board through formal and informal professional development opportunities throughout the 2007-2008 school year. The research suggests that a positive impact on students has resulted from integrated programming. This may provide the justification and motivation needed to encourage more teachers and schools to attempt integration.

A review of existing research conducted by Pang and Good (2000) found that most studies focused on integration at the elementary and middle school levels. In addition, research considered either achievement or attitude, but infrequently both. This



study will provide greater insight into the potential of science and mathematics integration at the secondary school level. It will also provide insight into the impact integrated instruction has on both the achievement and attitude of students.

Ultimately the most significant impact of this research will be improved student learning and attitude in science and mathematics. Just as this is the goal of any teacher at the beginning of a lesson, it was the goal of this study to determine the conditions that ensure that this will happen.

### **Theoretical Framework**

The integrated program that was developed for the purpose of this research was based on a theoretical framework assembled from a variety of sources. As will be examined in the review of the literature, a single, commonly accepted definition for integration does not exist. However, there is some common ground amongst many of the definitions and theories of integration that have been put forth. This framework is based on those commonalities. Drake (1998) states that most approaches to integration are based on a continuum that is arranged according to the amount of interconnectedness. On this continuum, the greater the number of connections made, the greater the degree of integration. Drake suggests that different approaches to curriculum integration are necessary and more or less appropriate depending on the context in which they are applied. The degree of integration does not suggest superiority of one method over another. In fact, integration of two subjects, such as science and mathematics, is simply one step on a larger continuum that moves along to transdisciplinary studies, which “transcends the disciplines” (Drake, p. 21). Ultimately, the subject becomes the vehicle with which students can seek to better understand their world and not an end unto itself.

This research, then, is not attempting to show that there is one best method of integration. It is instead seeking to find if integration, in any form and positioned at a variety of places along the continuum, has any impact on student learning and attitude.

### **Outline of the Remainder of the Document**

Chapter Two will review research on the integration of science and mathematics curriculum. The literature review will address the political and social context of the call for integrated programming in science and mathematics. The challenges of defining integration will be discussed, followed by an overview of various models of integration that have been proposed in efforts to provide a common understanding of what integration really means in practice. The evidence will be examined and summarized in terms of whether it supports the belief that integration of science and mathematics is beneficial for students and in what ways the benefits might be manifested. Finally, the potential pitfalls and hazards of integrated science and mathematics will be examined.

Chapter Three will explain the methodology and procedures that were designed in order to collect five sets of data, including the results of the grade 9 EQAO mathematics testing, the science exam results, the grade 9 final performance assessment task results in both science and mathematics, and the pre- and postcourse attitudinal survey results for both science and mathematics. A rationale for the collection of each set of data will be explained, as well as why a quasi-experimental design was chosen for the research. The process for the selection of participants will be described, along with an overview of the classroom structures and procedures that distinguished the integrated classroom from the regular classroom. The chapter will close with a discussion of the methodological assumptions and limitations of the study.

Chapter Four will present a detailed account of the findings from each of the five sets of data. Any interesting or anomalous data will be highlighted, and themes or patterns evident in the data will be identified, explained, and summarized.

Chapter Five will explain conclusions and implications of the study's findings. The findings will be used to address questions raised in the literature review that formed the basis for the study. The conclusions will then be used to explain implications for integrated instruction to learning in science and mathematics.

## **CHAPTER TWO: REVIEW OF RELATED LITERATURE**

The study of science and mathematics has long been viewed as naturally connected and a powerful means to educate students about an increasingly mathematical and scientific world. This idea is reflected in Meier's (1998) claim that "educators who do not integrate are missing an opportunity to help students understand the world in which they live" (p. 438). This sentiment is echoed by Brooks and Brooks (1993), who implied that the learning achieved is greater when it is linked together with learning that already exists. "Deep understanding occurs when the presence of new information prompts the emergence or enhancement of cognitive structures that enable us to rethink our prior ideas" (p. 15). The connections between science and mathematics already exist and are powerful. As McBride and Silverman (1991) noted, a close interrelationship exists between science and mathematics, as they share a common grounding in the use of quantitative problems, the use of variables, and the study of relationships. In other words, they are perfect partners when endeavouring to apply integration strategies as there is already a philosophical overlap between the two disciplines.

### **Social and Political Implications of Integration**

The focus on science education has become an international imperative. In the United States, the National Science Education Standards (cited by Yager, 2000) state the four main goals that science education should achieve, allowing each student to:

1. Experience the richness and excitement of knowing about and experiencing the natural world;
2. Use appropriate scientific processes and principles in making personal decisions;

3. Engage intelligently in public discourse and debate about matters of scientific and technological concern;
4. Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person throughout their careers. (pp. 327-328)

Similar ideas were broadly stated by the Science Council of Canada (1984) when they stated that “science education must be the basis for informed participation in a technological society, a part of a continuing process of education, a preparation for the world of work, and a means for students' personal development” (p. 10). Stated even more precisely in the Common Framework of Science Learning Outcomes, K-12: Pan Canadian Protocol for Collaboration on School Curriculum (Council of Ministers of Education, Canada, 1997), the goals of science education are to:

1. encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours;
2. enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others;
3. prepare students to critically address science-related societal, economic, ethical, and environmental issues;
4. provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies appropriate to their interests and abilities;

5. develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology, and the environment. (section 3)

The Ontario curricula for science and mathematics reflect the spirit of these goals.

The Ontario Curriculum, Grades 9 and 10, Science (Ministry of Education, Ontario, 1999a) states that scientific literacy is the goal of science education, and that “scientific literacy can be defined as possession of the scientific knowledge, skills and habits of mind required to thrive in the science-based world of the twenty-first century” (p. 2). In a similar fashion, the Ontario Curriculum, Grades 9 and 10, Mathematics (Ministry of Education, Ontario, 1999b) document states that “today’s mathematics curriculum must prepare students for their tomorrows” (p. 3).

The Ontario Curriculum, Grades 9 and 10, Science (Ministry of Education, Ontario, 1999a) specifically mentioned that science has many connections to other disciplines and that these connections are an important consideration in teaching science to achieve the goals previously outlined. Science, it suggests, cannot be viewed as simply a collection of information but rather a complex web of ideas that extend into many other disciplines. Yager (2000) suggested that one of the key domains necessary to see science education meet the goals set for it was that of applications and connections:

It seems pointless to have any science program if the program does not include a substantial amount of information, skills, and attitudes that can be transferred and used in students’ everyday lives. Also, it seems inappropriate to divorce “pure” or “academic” science from technology.... Some dimensions of this domain are seeing use of scientific concepts in everyday life experiences; applying learned science concepts and skills to everyday technological problems, understanding

scientific and technological principles involved in household devices; using scientific processes in solving problems that occur in everyday life; understanding and evaluating mass media reports of scientific developments, making decisions related to personal health, nutrition, and lifestyle...integrating science with other subjects; using information “learned” in completely new contexts relating science concepts and processes and solving current issues and problems. (Yager, p. 338)

### **Definitions of Integration**

The call to integrate the science and mathematics curricula is hardly new. The drive to connect these two subjects has been evident in some form over the past century and has certainly provided fodder for more focused debate and discussion in the past 20 years (Pang & Good, 2000). So, then, what does integration mean? There are many deceptively simple definitions for integration. It can be thought of as the “extent to which teachers use examples, data, and information from a variety of disciplines and cultures to illustrate key concepts, principles, generalizations, and theories in their subject area or discipline” (Banks, 1993, p. 25). Beane (1995) describes it somewhat more broadly, saying that “curriculum integration, in theory and practice, transcends subject area and disciplinary identifications; the goal is integrative activities that use knowledge without regard for subject or discipline lines” (p. 619). Lederman and Niess (1997) defined integration as the blending of the two subjects to the point where neither was clearly distinguishable. As Czerniak, Weber and Sandmann (1999) pointed out, when it comes to defining integration, “ambiguity is evident in the sheer number of words used to describe integration: interdisciplinary, multidisciplinary, transdisciplinary, thematic, integrated, connected, nested, sequenced, shared, webbed, threaded, immersed, networked, blended,

unified, coordinated and fused” (p. 422). Certainly it is evident that for every way of naming integration, there is a slightly different way of defining it!

In 1991, a conference called “A Network for Integrated Science and Mathematics” was held at the Wingspread Conference Centre in Wisconsin, and five plenary papers were presented offering a variety of opinions and viewpoints about the issue of science and mathematics integration. It was noted that, when the literature was reviewed, a consistent definition of integration could not be found; this in turn led to an inability to compare research in a meaningful way (Berlin, 1994). The conference presented, among others, the following task for participants: “Define integration and develop a rationale for integrated science and mathematics teaching and learning” (Berlin, p. 33). Despite the efforts of participants, a clear definition of integration in the context of science and mathematics education did not emerge. The closest thing to a definition was the proposal put forward by some that “integration infuses mathematical methods in science and scientific methods in mathematics such that it becomes indistinguishable as to whether it is mathematics or science” (Berlin & White, 1992, p. 341). The literature suggests that this search for a meaningful definition continues without a clear resolution.

### **Models of Integration**

The theoretical framework for this research is based on the concept that there is no one superior method or definition for integration. Rather, it is a continuum that allows for movement in order to best suit the context of the learning (Drake, 1998). This idea of a continuum can be seen emerging and evolving in the literature.



Based on experiences from the Wisconsin conference, Berlin and White (1994) made an effort to address the issue of a definition of integration with the Berlin-White Integrated Science and Mathematics Model. Berlin and White hoped that the model would provide a useful definition while being necessarily considerate of the differences of opinion that exist. In this model, integration is based on six aspects that must be considered. They are:

1. Ways of learning: integration based on how students experience, organize, and think about science and mathematics;
2. Ways of knowing: using integrated science and mathematics activities to move between inductive and deductive ways of knowing;
3. Process and thinking skills: integration based on the common methods of investigation found in both science and mathematics;
4. Content and thinking skills: integration based on the concepts or ideas that overlap the two disciplines;
5. Attitudes and perceptions: integration based on what students believe and feel about science and mathematics;
6. Teaching strategies: making instructional decisions that will assist students in bridging the gap between science and mathematics. (pp. 3-4)

Davison and Miller (1995) also attempt to create a model for science and mathematics integration by breaking it into types:

1. Discipline specific integration, which involves two or more different branches of mathematics or science and can be effectively handled through the use of a complex and multifaceted problem;

2. Content specific integration, which involves the selection of preexisting curriculum objectives from science and mathematics, which are then woven together to create lessons that address both;
3. Process integration, which involves the use of common science and mathematics problem-solving processes to conduct real-life activities and solve problems;
4. Methodological integration, which has the student investigate issues using strategies such as inquiry, discovery, and the learning cycle;
5. Thematic integration, which uses a theme that becomes the framework for the interaction of the disciplines, often even beyond science and mathematics.

Another way of organizing a model for integration is by the use of a continuum. Lonning and Defranco (1997) suggested a continuum that has purely mathematical concepts at one end and purely scientific at the other. The midpoint of the continuum would exist only “when the science and mathematics content are both part of the curriculum for a particular grade level and the instruction is delivered in a meaningful way, the activities are classified as ‘balanced’ on the continuum” (p. 213). The authors noted the importance of not only mixing disciplines, but doing so in a manner that fully considers the grade level and curriculum for each. If an activity is more meaningful in one discipline than in another, then it is closer along the continuum to that discipline.

Huntley (1998) built on this idea of a continuum. The author suggested five categories for interaction between science and mathematics:

1. Mathematics for the sake of mathematics,

2. Mathematics for the sake of science,
3. Science and mathematics,
4. Science for the sake of mathematics,
5. Science for the sake of science. (p. 321)

Huntley viewed these as continuous categories rather than discrete and compares the middle “science and mathematics” as being similar to Lonning and Defranco’s (1997) center, which involved equal treatment of both disciplines. However, the middle is seen differently here; rather than mere equal treatment, the middle represents the point at which

the disciplines science and mathematics interact and support each other...there is a synergistic union of the two disciplines, the result being an activity or curricular unit in which the interactions between the disciplines result in students learning more than just the science and mathematics content contained therein. (p. 322)

A different approach to a continuum was given by Hurley (2001) and is based on a historical overview of integration-related literature. This continuum, however, progresses from least integrated to most integrated, rather than moving between the two disciplines:

1. Sequenced. Science and mathematics are planned and taught sequentially, one preceding the other;
2. Parallel. Science and mathematics are planned and taught simultaneously through parallel concepts;
3. Partial. Science and mathematics are taught partially together and partially as separate disciplines in the same classes;

4. Enhanced. Either science or mathematics is the major discipline of instruction, with the other discipline apparent throughout the instruction;
5. Total. Science and mathematics are taught together in intended equality. (p. 263)

Hurley states, in conclusion, that research suggests that rather than seeking a general definition for integration, it is necessary to acknowledge a need for multiple definitions and models.

### **Impact on Learning and Attitude Through Integration**

As the quest for the ideal definition and model for integration continues, it is noted that the idea that “integrated is better” is often an untested one. As educators continue to search out new ways to make connections between science and mathematics that will enrich the learning that is taking place, there is seldom a pause to examine what the benefits are and whether they are worth all the trouble. It is odd, then, how the mantra of integration has come to be so widely accepted. What evidence exists to support integration? Very little, suggests Berlin (1994), who laments this fact, noting that without such evidence there simply will not be the change to practice that is desired. Part of the lack of evidence for integration stems from the ambiguous definition of integration mentioned earlier. That, however, is compounded by a lack of empirical evidence. Czerniak et al. (1999) noted in their review of the evidence that most of it is anecdotal in nature, consisting of reports from educators. While ringing with positive endorsements, these reports do not provide the hard evidence that many science and mathematics educators would likely find most convincing. The little empirical evidence that exists is rendered less useful, they suggest, when the diversity of operational definitions are considered. Nonetheless, between the qualitative and the quantitative, there exist

tantalizing hints and clues that integrated instruction offers a means to improve instruction beyond the possibilities of a traditional single-discipline classroom model.

Such richness of possibility is evident in research such as that from Venville and Wallace (1998), who examined 16 Australian schools reportedly involved with efforts to integrate science and mathematics. Teachers noted improved understanding of science and mathematics when students applied their knowledge to technology projects, and better quality products as well. Improved transfer of understanding and skills between subject areas was observed, and more reinforcement of key ideas was possible. Venville, Wallace, Rennie, and Malone (2000) examined students in a grade 9 class that was involved in an integrated project. Venville et al. found that by using knowledge in an application environment, “contextualization and relevance resulted in the students’ learning being connected to the task and bridging subject disciplines, a learning which seem enhanced beyond its compartmentalized origins” (p. 34). The teachers involved also benefited from the process, reporting greater satisfaction, renewed energy, and excitement at their involvement with the process. Similar conclusions were made by Ross and Hogaboam-Gray (1996), who examined the impact of a Math-Science-Technology (MST) integrated curriculum on grade 9 students. Student achievement was improved, and greater application of concepts took place. Further to this, it was also noted that female students performed better with an integrated approach than they did when the science and mathematics curricula were taught separately.

Empirical studies do exist to support Beane’s (1995) contention that “young people tend to do at least as well, and often better, on traditional measures of school achievement when the curriculum moves further in the direction of integration” (p. 618).

J. Wang (2003) noted that since the Third International Mathematics and Science Study (TIMSS) and a later repeat of this study (TIMSS-R) used both science and mathematics tests to measure student achievement, they provided an opportunity to analyze the relationship in achievement between the two subjects. He stated that “a moderate to strong degree of relationship...has been found between mathematics and science achievements” (p. 12). He concluded that “integration effort can account for 36%-60% of mathematics or science performance at the 8<sup>th</sup> grade level” (p. 12) and suggested that efforts to integrate the two subjects would improve student achievement on mathematics and science-linked questions.

Austin and Hirstein (1997) conducted research more specifically aimed at the impact of integrated instruction in science and mathematics. They examined the data collected from 23 classrooms following the use of the SIMMS (Systemic Initiative for Montana Mathematics and Science) curriculum which had been designed specifically to integrate science and mathematics. The curriculum consisted of 16 units of 2-3 weeks each, resulting in a full year of study in science and mathematics for grade 9 students. Six non-SIMMS classes were used as a comparison to the experimental group. At the conclusion of the course, two assessments were administered. One was a series of open-ended tasks, while the other was the mathematics portion of the Preliminary Scholastic Assessment Test (PSAT). In addition, students completed an attitude survey that measured student attitude toward mathematics. These surveys were completed at the beginning and the end of the year. Austin and Hirstein found that student performance on the open-ended tasks was improved in the integrated classes. The PSAT scores were not negatively affected by participation in the SIMMS program. Finally, the attitude surveys

show that students participating in the SIMMS classrooms become more confident in their abilities to do mathematics (Austin & Hirstein).

Judson and Sawada (2000) used a junior high school classroom as the focus of their research. They examined two classes of students during a 3-week unit on statistics. Both classes had the same mathematics teacher and received the same mathematics instruction. However, one class had a science teacher who made a conscious effort to integrate the mathematics that the students were learning into the science classroom. This teacher worked very closely with the mathematics teacher to plan around the mathematics as closely as possible. A variety of strategies were employed by the science teacher. Open-ended questions were used to encourage data collection and organization. Students developed their own strategies for gathering and interpreting information. Probeware and graphing calculators were also used to encourage students to manipulate and display data in a variety of ways. At the end of the statistics unit, students completed a mathematics test on the material that they had covered during the unit. Judson and Sawada found a statistically significant difference between the two groups, with 54% of students in the traditional science class receiving a grade of D or F on their test and only 4% in the integrated science class receiving that same grade. In addition, 35% of students in the traditional science class achieved a grade of A or B on the test compared to 75% of the students in the integrated group. These results show that the integration of mathematics into a science class does impact the achievement of students in mathematics. A comparison of results in science suggested that the science marks did not show a similarly significant difference. Both the traditional and integrated classes performed equally well on a district-wide science test.

Elliot, Oty, McArthur, and Clark (2001) examined the impact of integration at the college level. Noting a dramatic increase in attention to integrated curriculum, they suggested that “with all of this interest in interdisciplinary courses, it is natural to ask what effect these courses have on students” (p. 811). Elliot et al. compared the critical thinking skills, problem-solving skills, and attitudes towards mathematics of two groups of students: those enrolled in a traditional College Algebra course and those enrolled in an interdisciplinary course entitled “Algebra for the Sciences.” The data were collected twice, once in the spring and once in the fall. The first time the courses were provided, the students were randomly assigned to the integrated course and did not know that they were participating in a different course from their classmates. For the second iteration of the course, students self-selected for participation. It is interesting to note that no significant differences were found in any of the measures between the randomly assigned group and the self-selected group. Elliot et al. found students in the Algebra for the Sciences course did not show any significant difference in problem-solving skills at the 0.05 level. Only one statistically significant difference was noted in critical thinking skills, as the students in the Algebra for the Sciences course had a better score in the inference category. The attitude survey results were more promising. Overall, students in the Algebra for the Sciences course had a more positive attitude toward mathematics after completing the course than did the students in the College Algebra course.

A study by Beichner (1999) was conducted at the university level within a faculty of engineering. Students accepted into the engineering program were offered the option of participating in Integrated Math, Physics, Engineering and Chemistry (IMPEC) curriculum. The program was designed to rely on student collaboration in the completion



of coursework that focussed on problem-oriented, activity-based instruction. The course was conducted for two consecutive school years with two different groups of first-year students. Students were organized into collaborative, heterogeneous teams that encouraged positive interdependence. Beichner examined quantitative data including the success rate, defined as the “percentage of students with grades of C or better in science, math and engineering courses” (p. S20), performance on problem-solving-focused exams, and performance on conceptual evaluations such as the Force Concept Inventory. In addition, data were collected to measure satisfaction and self-confidence. Beichner found that in every measure of success, the IMPEC students did better than their cohorts in the traditional engineering program. IMPEC students had a success rate of 69% compared with 52% for students in the traditional group during the first year of the study and 78% versus 50% in the second year. The IMPEC students performed better on exams, with an average of 80% compared to 68% for traditional students. Finally, on the conceptual evaluations, the IMPEC students “performed at a much higher level ...than did a national sample of traditionally taught students” (p. S21). When the results of the attitudinal surveys were examined, it was found that “compared to students in the control group and to all students in the regular freshman orientation course, the IMPEC students finished with significantly higher levels of confidence in their abilities in science and mathematics, writing, speaking, and computer skills” (p. S20).

Hurley (2001) conducted a broad review of empirical data by examining 31 studies relating to integrated studies in math and science ranging from 1935 through 1997 and drew some interesting and cautionary conclusions. According to evidence culled from past decades, student achievement was slightly more improved in science than in

mathematics when the two subjects are integrated, and the degree of difference depends on the manner in which integration takes place. Some qualitative evidence suggested that less time was given to mathematics when it was taught within an integrated model. Hurley posed the thought-provoking question, “Integrating mathematics into science might be good for science, but what might be best for mathematics?” (p. 265). It is noteworthy that the best results for mathematics were achieved when mathematics was taught in sequence with science; in other words with mathematics first and science following.

The idea that integration can improve performance is tantalizing. More critical, though, may be the ability of integration to bring about attitudinal changes. Hurley (2001) states:

When the studies from the past two decades were examined qualitatively for additional evidence for or against integration on variables beyond achievement, little was found. A few studies measured mathematics anxiety, mathematics motivation, or attitude towards either mathematics, science or school; few differences were discerned from the measurements. (p. 263)

Despite the lack of evidence to date, this is perhaps where the elusive jackpot of potential for integration is found. George and Kaplan (1996) argued that attitudes are critical as they influence achievement, increase enrolment in science courses, and stimulate interest in scientific careers. Venville and Wallace (1998) found that, when examining the data collected, group and individual work skills were enhanced, co-operation and collaboration increased, and students become more responsible for their own work. Austin and Hirstein (1997) found that students became more mathematically

confident and empowered after taking a grade 9 integrated science and mathematics course. Outcomes such as these suggest that the integration of science and mathematics has a significant effect on the achievement and attitude of students and is worthy of further and more detailed consideration when weighing the merits of integration.

### **Negative Implications Associated with Integration**

Along with the possibilities promised by an integrated science and mathematics curriculum, the literature holds many warnings of dangers that might lie ahead and pitfalls that should be avoided. At the most practical level there are warnings to be heeded by student, teacher, and administrator. Venville and Wallace (1998) suggested that students sometimes are unable to manage their time and plan effectively for the type of long-term projects that integration often includes. In addition, they suggested that teachers need due warning about the significantly increased workload and the slow, “trial and error” nature of implementing an integrated program. According to Meier (1998), administrators must be aware of the need for common planning time for teachers, an altered physical organization of classrooms in the school, and the need for easy access to the different resources, equipment, and consumable supplies needed for effective integrated instruction. Omitting such seemingly minor details can often be the tiny leak that eventually sinks the ship and is, therefore, worthy of consideration.

Broader, more philosophical warnings must also be heeded. Among these is the suggestion that sometimes the possibilities of integration may already be diminished by the curriculum framework and structures within which they must exist. Davison and Miller (1995) asked whether efforts to integrate mathematics and science represented genuine integration or were simply cosmetic changes that gave the appearance of

integration. Mason (1996) suggested that the sequential nature of mathematics could potentially leave gaps and create confusion for students if mathematics is put into the curriculum in “bits and pieces” without the coherence the subject demands. In addition, Mason cautioned against the trivialization of learning for the sake of integration. His point is well taken; for example, “a poem about photosynthesis may not help one understand photosynthesis as a process, or poetry as a genre” (p. 266). This fear of lost depth is evident as Ross and Hogaboam-Gray (1996) stated that “there are risks in curriculum integration. The structures of the disciplines, their internal organization, of ideas and principles, could be lost in a merger” (p. 1). Ross and Hogaboam-Gray also suggested that the connection across subjects in one grade level might make it harder to connect with the courses that follow in the subsequent school years, perhaps due to this feared loss of depth and organization.

In reviewing the literature concerning the integration of science and mathematics, several significant themes emerge. Most significant is the problem that there does not yet exist a commonly accepted and universally understood definition of integrated science and mathematics. This makes it difficult for educational researchers to study this topic in a focused manner and thus draw conclusions that might convince curriculum designers and teachers that the integrated approach should be the standard and not the exception. Qualitative data exist, and these seem to hint that perhaps the benefits of integration, although present and important, are not necessarily measurable with the yardsticks that are traditionally employed. As Beane (1995) concluded:

Curriculum integration centers the curriculum on life itself rather than on the mastery of fragmented information within the boundaries of subject areas. It is

rooted in a view of learning as continuous integration of new knowledge and experience so as to deepen and broaden our understanding of ourselves and our world. Its focus is on life as it is lived now rather than on preparation for some later life or later level of schooling. It serves the young people for whom the curriculum is intended rather than the specialized interests of adults. It concerns the active construction of meanings rather than the passive assimilation of others' meanings. (p. 622)

Although a single definition and understanding of integration appears to be the ultimate goal of research, the reality in education is that perhaps such a thing does not exist and cannot exist such that it would be ideal in every classroom. The many models of integration, then, provide valuable guides and provide structures upon which integration may be constructed. The models all exist along the continuum of connectedness described by Drake (1998). The evidence of their efficacy provides constantly shifting guidelines and helps to build success with each successive effort at integration of science and mathematics.

### **Summary**

Science and mathematics education are charged with social and political significance. Success in these areas is seen as an indicator of the efficacy of an education system as a whole and as a measure of the advancement of a society. Recent changes in science and mathematics curricula in Ontario, as well as the introduction of standardized mathematics assessment, have caused a greater scrutiny and more intense examination of science and mathematics education in the province. Integration of the two disciplines is an idea that is suggested as a means to improve achievement in both.

Although the idea of integration is generally known, the actual definition for integration is varied. There is no common understanding of what integration actually means. Several models of integration have been proposed. The Berlin-White Integrated Science and Mathematics Model (1994) outlines six different ways to consider integration, while Davison and Miller (1995) propose five categories depending on how the integration is handled. Lonning and DeFranco (1997) prefer to think of a continuum of integration, rather than discrete categories, based on the degree of science or mathematics being taught, and this model is further developed and built upon by Huntley (1998). In both models, the center of the continuum is the point at which the curriculum is fully and meaningfully integrated. Hurley (2001) clarifies this definition with a more concrete description of the nature of instruction that would take place along such a spectrum of integration.

There is little evidence in support of the idea that integration will improve student learning, although the research suggests that there are benefits to be realized from efforts to integrate science and mathematics. These benefits include increased student understanding, greater application of concepts, and improvement in performance on open-ended tasks. Although significant improvements on traditional standardized tests are not generally noted, students who experience integrated instruction tend to do at least equally as well as students in nonintegrated learning environments. Also noted in some studies is the improved confidence that students in an integrated program seem to attain. This suggests that attitude may also be influenced by integrated instruction, although this has not been supported by sufficient research. Attitude is an important consideration, as it

is thought to influence achievement, future enrolment in science and mathematics classes, and eventual career choices.

Despite the potentially positive impact that integration could have, there are limitations that need to be considered. Among these are practical considerations such as the extra demands of time and organization placed on both the student and the teacher and the need for more flexible and diverse classroom and scheduling arrangements within a school. Broader concerns would include the concern for fitting integration into an existing curriculum framework and the avoidance of trivialization of either discipline for the sake of integration. Finally, the lack of a commonly accepted definition for integration is an ongoing limitation that certainly creates challenges when designing and attempting to study the impact of an integrated program in science and mathematics.

## **CHAPTER THREE: METHODOLOGY**

The purpose of this study was to determine whether the integration of grade 9 academic science and mathematics curricula had any impact on student academic performance and attitude towards science and mathematics. Ideally this investigation would have been conducted with a purely experimental design, but this was not possible due to the constraints that occurred as a result of being unable to obtain a randomly selected sample of students in the treatment group. The specifics of the initiation of the integrated program and the organization that resulted are described, along with an explanation of how student candidates were selected to be members of the experimental or test group. Further, included in this chapter is a description of the instrumentation used, followed by a precise description of the procedures used by the researcher. Limitations of the methodology are outlined and explained, and the ethical considerations of this research are discussed. To ensure confidentiality, pseudonyms are used throughout this study for the names of the school board and secondary school, Suburban Board of Education and Midtown Secondary School.

### **Research Design**

This research was designed to answer the following questions:

1. Does this integrated approach to science and mathematics instruction have any impact on the achievement of students in the integrated class compared to those in a traditional setting?
2. Are there any notable differences in attitude toward either subject area for students in the integrated class?



In this quasi-experimental design, the treatment group and control group are defined according to the following:

Treatment group	Students enrolled in both grade 9 academic science and grade 9 academic mathematics and entering their first year of high school who were randomly selected from submitted parental permission forms for participation in the integrated program.
Control group	Students enrolled in both grade 9 academic science and grade 9 academic mathematics and entering their first year of high school who were randomly selected from the regular grade 9 academic science and mathematics classes

All students were informed about the integrated science and mathematics program at parent information evenings, through newsletters, and through feeder school visits. All students enrolling in grade 9 academic science and mathematics were invited to apply to participate and were made aware of the fact that selection to participate would be random.

The treatment and control groups were both taught using the expectations of the Grade 9 academic science and mathematics curricula as given by the set of expectations outlined in *The Ontario Curriculum, Grades 9 and 10, Science* (Ministry of Education, Ontario, 1999a, pp. 6-14) and *The Ontario Curriculum, Grades 9 and 10, Mathematics* (Ministry of Education, Ontario 2005, pp. 29-37). The independent variable in this research is the nature of the instruction to which the two groups were exposed. The treatment group received the courses with a single teacher using an integrated approach,

meaning that both the content and processes of the grade 9 science and mathematics curricula were integrated according to the definitions of integration given by Davison and Miller (1995). Lessons were designed using concepts from the curricula mandated by the Ontario Ministry of Education while similarly drawing upon the problem-solving processes outlined in both documents. Integration was partial, according to Hurley (2001), as the science and mathematics were taught “partially together and partially as separate disciplines in the same class” (p. 263), while the control group had the science and mathematics courses taught in a separate classroom with different teachers and with no attempt to integrate the two curricula. Throughout the study, the following five dependent variables were measured:

1. Performance on the Ontario Education Quality and Accountability Office (EQAO) mathematics assessment was measured. This provided an ideal comparison, as it was a standardized test delivered in a highly controlled and rigorous manner.
2. Final exam performance in science was also measured, which was a suitable variable to examine since all students wrote almost identical exams under the same conditions. Some slight differences were present in the exam as half of the students in the control group wrote their exam at the end of Semester 1 instead of the end of Semester 2 with all remaining control and treatment group students.
3. Performances on final assessment tasks in mathematics were compared, although the results may not have been as reliable since the tasks were carried out in individual classrooms and administered by different teachers; some variations in

delivery of instructions and time allotment may have occurred. Evaluation of the tasks was agreed upon by the participating teachers and a common rubric was used to grade the submissions.

4. Performances on final assessment tasks in science were compared and, as with the mathematics, the results may not have been as reliable since the tasks were carried out in individual classrooms and administered by different teachers; some variations in delivery of instructions and time allotment may have occurred. Evaluation of the tasks was agreed upon by the teachers, and a common rubric was used to grade the submissions.
5. Attitude surveys (see Appendix A and Appendix B) were conducted at the beginning and the end of each science and mathematics course or at the beginning and end of the integrated course, providing data on attitudinal changes that may have occurred within the treatment and control groups.

By examining the impact of the independent variable (the method of curriculum delivery) on the dependent variable (student success, as given by final evaluation, and attitudinal changes, as given by survey results), it was possible to draw conclusions on the impact of an integrated science and mathematics program on the success (as measured by the results on the EQAO, final performance assessment tasks in math and science, and the science exam) and attitudes (as measured by the survey results) of the students in the treatment group.

The research was of a quasi-experimental nature due to the fact that groups used within the experiment were not selected randomly. Results from the grade 6 EQAO assessment were available to be used to control for any difference in math ability that

may have existed between the two groups. The possible discrepancies between the treatment and control groups may have resulted from two levels of sorting that took place during the application and selection procedure during the spring of 2005. Students could not be placed in the pilot Integrated Science and Mathematics Program without parental knowledge and consent. Information about the program was disseminated to parents at information evenings held at the high school and through literature distributed to students, who were expected to take it home and ask their parents to review it. This process by its very nature resulted in students being sorted into two groups: those whose parents attended information nights and read information coming from the school and those who did not. Such behaviour may have been indicative of parental involvement with the students' school careers, which may in turn have an impact on the success and attitude of students. A further secondary sorting occurred within this group. Parents made a conscious decision to apply to have their child entered into the lottery process for selection, which suggests that either the parent or student had a particular attitude toward science and mathematics. Either they valued such a program and perhaps had already experienced success in science and mathematics or the parent or child viewed the integrated course as a means of motivating and engaging a weaker student in order to bolster performance. From this pool of applicants, selection for the program was conducted by a draw, but the process to this point had been such that significant sorting had likely already occurred.

The null hypothesis in this investigation is that there is no difference between the two groups, the control group enrolled in regular science and mathematics classes and the treatment group enrolled in the integrated science and math classes, either in terms of

student achievement as measured by performance on the assessment tasks described or in attitude as measured by the surveys. The null hypothesis can be described by the equation

$$H_0 : \mu_{Tatt} = \mu_{Catt}$$

$$\mu_{Tach} = \mu_{Cach}$$

where,

$H_0$  represents the null hypothesis

$\mu_{Tatt}$  represents the attitude of the treatment group

$\mu_{Catt}$  represents the attitude of the control group

$\mu_{Tach}$  represents the achievement of the treatment group

$\mu_{Cach}$  represents the achievement of the control group

The first alternative hypothesis is that there will be some impact on attitude for the treatment group compared to the control group, but no difference in achievement. The first alternative hypothesis can be represented by the equation

$$H_1 : \mu_{Tatt} \neq \mu_{Catt}$$

$$\mu_{Tach} = \mu_{Cach}$$

where,

$H_1$  represents the first alternative hypothesis.

The second alternative hypothesis is that there will be some impact on achievement for the treatment group relative to the control group, but not on attitude. The second alternative hypothesis can be represented by the equation

$$H_2 : \mu_{Tatt} = \mu_{Catt}$$

$$\mu_{Tach} \neq \mu_{Cach}$$

where,

$H_2$  represents the second alternative hypothesis.

The final alternative hypothesis is that there will be some impact on both success and the attitudes of the treatment group relative to the control group. The third alternative hypothesis can be represented by the equation

$$H_3 : \mu_{Tatt} \neq \mu_{Catt}$$

$$\mu_{Tach} \neq \mu_{Cach}$$

where,

$H_3$  represents the third alternative hypothesis.

### **Selection of Site and Participants**

The principal investigator was interested in piloting an integrated science and mathematics unit within Midtown Secondary School in Midtown, Ontario. The school principal was approached, and she indicated that she would support such a pilot program and suggested that it would be possible within the next few years. Three years later, the principal investigator sought and received permission from the school principal to begin planning a pilot Integrated Science and Mathematics Program to commence the following September.

The school principal indicated that all incoming grade 9 students for September should be made aware of the availability of such a program and that one section of 28 students would be available for the program. Parents must have given informed consent in order for a student to be placed in the integrated program. Information about the program was provided during Grade 8 Parent Evening in the spring and by letters sent home to all families of grade 8 students. It was made clear to parents that selection of students for the program would be done randomly from the pool of applications received.

Parents were asked to fill in a permission sheet indicating that they were willing to have their child(ren) entered into the pool. Permission sheets were returned to the feeder school with option sheets and could also be dropped off at the Midtown Secondary School office before a given deadline. All forms were handled by guidance personnel in the Student Services department. Questions from parents were directed to the principal investigator and handled by phone, e-mail, and face-to-face conversations.

Once the deadline for option sheets had passed, the forms were assembled into a single location, and it was determined that over 75 students had applied to be in the integrated program. At that time, the process of setting the course timetable had begun, and it was decided that it was possible for a second integrated class to be opened to allow a greater number of interested students to take part in the program. The Head of Guidance randomly selected 58 students from the pool of interested participants. This was accomplished by drawing names of applicants out of an envelope. Those students selected and their families were notified by mail that they had been selected. The feeder schools were also provided with lists of students who had been selected for the program. Once selected, students were placed into the integrated program on the timetable. Remaining students were randomly assigned to regular classes through computer timetabling software. This entire process was done by the guidance department without input or influence from the researcher. This was an important consideration, as it avoided any potential issues around students being selected in a manner that might influence the success of the integrated program.

In September, letters were sent home to all students registered in both grade 9 academic science and mathematics informing them of the research that was taking place

and requesting their permission to include their child(ren) in the research. Replies were collected from all students. At the end of the data collection, the students in the regular, nonintegrated science and mathematics classes were numbered in their class lists, and then a random number generator was used to select a group of 58 participants. This group became the control group. The treatment group and the control group had the same number of participants.

### **Instrumentation**

Yager (2000) suggests that education must address more than simply curriculum and learning. Another significant priority must be the affective domain. He includes in this domain the developing of positive attitudes towards self, making constructive decisions about personal life that include career choices and social and environmental issues, and includes positive attitudes towards science study, classes, and teachers as indicators of this attitude. The instrumentation selected for measuring attitude attempted to measure these attitudes.

The attitudinal survey used in this research was adapted from a survey that was designed by the Council of Ministers of Education, Canada and administered in 1999 to 13- and 16-year-old students. As part of a larger survey entitled the School Achievement Indicators Program used across Canada in 1999, the questions were meant to measure, among other things, attitudes towards science (Council of Ministers of Education, Canada, 1999). The survey was developed using the work of M. Wang, Haertel and Walberg (1990), and specifically their research into the factors that influence student learning. Wang et al. found that the most important variables could be grouped into categories that show the strongest associations with learning. These include student



variables, which Wang et al. define as “variables associated with individual students, including...a variety of social, behavioural, motivational, cognitive, and affective characteristics” (p. 32), including attitude toward the subject matter instructed. Also important are classroom instruction variables, which are the “routines and practices, characteristics of instruction as delivered...quality and quantity of instruction provided...and classroom climate” (p. 32). In later work, Wang et al. (1993/1994) emphasize the importance of motivational and affective attributes as of increasing significance, as “effort and perseverance are now regarded by educational researchers as key attributes necessary for developing self-controlled, self-regulated learners” (p. 75). Questions relating to these factors were amongst those employed in the School Achievement Indicators Program.

Approximately 31, 000 students participated in the School Achievement Indicators Program survey, and results are available for comparison in this research. For the purposes of this research, select questions were taken from the sections of the survey designed to measure educational and career expectations, perceptions of school and science or mathematics, motivation and confidence, and the perception of the quality of the classroom experience in science or mathematics. Although the attitude survey was originally intended to measure perceptions and attitudes in science, by repeating the questions and replacing the word “science” for “math” it was possible to obtain attitudinal data for both subject areas. Other than this change, there were very few minor changes made to the wording of the original survey questions. The science and math surveys were identical except for the words “science” and “math” and were each on separate pages.

The survey questions were clustered to more specifically determine dimensions of attitude that may have been impacted by participation in the integrated program. The first question was analyzed on its own as a measure of whether students expected to engage in a career that required education in science or mathematics. The next set of questions, numbers 1 through 6, examined student perceptions of science and math at school. Questions 7 through 10 examined student motivation and confidence. Finally, questions 11 through 13 determined the perception of the quality of their classroom experience in science or math.

The EQAO mathematics assessment for grade 9 was also used as a means to measure success for the students. The test was designed and administered by the Education Quality and Accountability Office and was pilot-tested to ensure reliability and validity. The test is meant to provide a measure of the effectiveness of the curriculum and of the learning strategies employed as outlined by the Ontario curriculum documents, and thus provided some insight into the effectiveness of the integrated program in terms of mathematics instruction. In addition to the grade 9 results, the grade 6 results for the 2005-2006 grade 9 cohort were also obtained to allow for a more accurate analysis of any differences between the treatment and control groups.

The final science exam was a collaborative effort among the teachers responsible for the grade 9 science course in Semester 2. The teachers all provided input into the exams and contributed questions that they felt were effective in measuring knowledge and understanding in the students. The teachers agreed upon a common marking scheme to ensure that students' work was being evaluated fairly and consistently in each classroom.

The final performance assessment tasks in mathematics were handled in much the same manner as the science exam, although it was a very different type of assessment from the EQAO test. The grade team met several times to decide the logistics and timing of the assessment and then to write a 2-day assessment that would require students to solve problems and apply knowledge in a final assessment task. Group work was allowed (although not assessed) for portions of the assessment, but students worked independently otherwise. The assessment task was done during class time during the last 2 weeks of each semester. Once completed, teachers met again to look at the student work and to confirm the criteria for assessment of the task using a rubric.

The final performance assessment tasks in science were similarly planned and coordinated by the teachers responsible for the grade 9 courses. The science task consisted of a 3-day assessment that required students to demonstrate lab skills using particular equipment and to demonstrate competency in their inquiry skills. A different task occurred each day over 3 days; the first day was a circuit electricity task requiring the use of a multimeter, the second day was a biology task requiring the use of a microscope, and the third day was a chemistry task requiring the mixing of chemicals using spot plates. Once again, teachers met to look at the student work and to confirm the criteria for assessment of the task using a rubric.

Table 1 outlines the timeline for the administrative measures and treatment implementation that took place during this study.

Table 1

*Timeline of Administrative Measures and Treatment Implementation*

Time	Action
January year 1	Parents and students were introduced to Integrated Program at Grade 8 Information Night and at guidance sessions offered at the feeder schools.
February year 1	Students submitted signed consent forms to indicate their interest in participating in the program.
June year 1	Students were selected by lottery and notified by mail of their admission to the integrated program.
September year 1	The integrated program and Semester 1 for the control group began. Letters of Invitation for Participation in Educational Research and Informed Consent Forms were sent home to all students in either grade 9 academic science or mathematics and to the students in the integrated program. All students completed the prescience and/or premathematics attitude surveys.
January year 2	Data from science exam, science summative, and mathematics summative were collected for the Semester 1 students in science or mathematics. Students finishing their mathematics credit wrote the EQAO mathematics assessment. All students finishing a Semester 1 science or

*(table continues)*

Time	Action
February year 2	<p>mathematics course completed the corresponding postmathematics or postscience survey.</p> <p>Semester 2 began. Letters of Invitation for Participation in Educational Research and Informed Consent Forms were sent home to all students in either grade 9 academic mathematics or science who did not receive a letter in the first semester. All students taking Semester 2 science or mathematics completed the prescience and/or premathematics attitude surveys.</p>
May year 2	<p>All students in Semester 2 mathematics classes and all integrated students wrote the EQAO assessment for mathematics.</p>
June year 2	<p>Data from science exam, science summative, and mathematics summative were collected for the Semester 2 students in science or mathematics and for all integrated students. Students finishing their mathematics credit wrote the EQAO mathematics assessment. All students finishing a Semester 2 science or mathematics course and all students in the integrated course completed the corresponding postmathematics and/or postscience survey.</p>

*(table continues)*

Time	Action
October year 2	Results for the EQAO assessment were made available to the researcher. Grade 6 EQAO assessment results for the 2005-2006 cohort were obtained by the researcher.
June year 3	Parents of students who participated in the study received a letter debriefing them on the results of the study. A notice was placed in the school newsletter informing all parents of the results of the study.

### **Classroom Procedures**

The curriculum in the control group classrooms was delivered in the manner that each teacher typically uses, with teachers meeting regularly to set common times for testing and evaluation. Although each teacher had his or her own preferences when delivering the math and science curriculum, similarities existed in the structure of the programs. In math, the course was divided into the following five distinct units: Relationships, Algebra, Analytic Geometry–Part 1, Analytic Geometry–Part 2, and Measurement and Geometry. The units were taught in the same sequence and at roughly the same pace for each class. The same textbooks, graphing calculators, and manipulatives were used in varying degrees in all the classrooms. In science, the following four units were taught: Matter, Reproduction, Electricity, and The Universe. These units were not necessarily taught in the same order in each class due to constraints with equipment and resources. Teachers focused on previously agreed upon key learnings and made sure that each class participated in certain key investigations. Although the pace of teaching and curriculum in the control classrooms were similar, the instructional methods varied depending on the teacher.

In the treatment group, the pace and evaluation timeline was set and determined by a single teacher, the principal investigator, with input and assistance provided by the Head of Mathematics and the school principal. The integrated program was designed and implemented by the principal investigator. The integrated program was designed using the curriculum expectations for grade 9 science and mathematics as given by the Ontario Ministry of Education. The course was structured around four major units chosen for their high relevance and potential motivation to students. Although each unit included

major concepts from both the science and mathematics curricula, individual classes were run as either mathematics classes, science classes, or as a combination of both, depending on the unit and topic. Every effort was made to ensure that science and mathematics were taught in equal proportion.

The first unit taught was the Crime Scene Investigation (CSI) unit. The major mathematical focus of this unit was linear relationships. Students conducted experiments and analyzed data to determine how linear relations could be used to analyze a crime scene. They then began to explore the fundamentals of biology, examining the cell and the significance of DNA to the function of living things. This led to a consideration of the properties of DNA that make it such a useful tool in fighting and solving crime. An understanding of mitosis was used to look at how bacterial decay of an organism and insect population growth can be effective tools for determining the approximate time of a crime. Graphing skills and understanding of relationships came into play again as students considered the growth curves of bacterial colonies. Similarly, various reproductive strategies of living organisms were explored as students discovered that such things as pollen, seeds, insect larvae, and spores provide invaluable assistance in the solving of many crimes. Students considered the importance of good qualitative and quantitative observations and used both to examine and use chemical and physical properties to identify unknown substances.

The second unit was Mission to Mars. Students began their work by examining the planets in the solar system and collecting data that would support their decision as to why Mars would be a logical place for humans to explore. They considered the chemical composition of other objects in our solar system and universe and related this to their



understanding of matter. The students' research moved them into analytic geometry as they continued to collect and analyze data to find linear relationships and represent them mathematically. Once the students completed their research on the nature of the planets and the solar system, they began to make plans for a mission to the Red Planet, considering all the needs for such a journey and designing the technology and structures, including storage and living space that would be required. This allowed the students to explore many aspects of measurement and geometry in a meaningful way. They had to consider cost and effectiveness of their plans, which provided opportunities to consider optimal values of various measurements.

The third unit was Blackout, which used the current energy crisis in Ontario as a framework for studying electricity. The students learned the fundamentals of static electricity and current electricity through exploration and experimentation. They discovered relationships among voltage, current, and resistance in circuits that they set up. Algebra was used as the students manipulated equations and used substitution to calculate power, energy, and ultimately the cost of electricity in the home. With this understanding, students then examined the present situation in Ontario and used a problem-solving model to determine the best solutions to the energy crisis. The students designed and constructed an electronic device to be used in the event of a blackout, for instance, a freezer alarm or back-up lighting system.

The final unit was Weird Science, and it examined some of the interesting science that surrounds the students. For example, the students looked at density and asked why some cans of pop float while others sink. They experimented with cereal to see if they could get the iron out of it using a magnet and then calculate the percentage of iron in

their corn flakes. The students analysed popular myths and determined whether there was any scientific or mathematical validity to them. Although not organized around a specific topic or theme, this unit worked well in that it allowed the students to explore some ideas about which they were curious and allowed the teacher to bring in any concepts or skills that may not have been covered as fully as desired during earlier units.

Although the four units were used to provide a context and relevance to the science and mathematics that was covered, not all of the science and mathematics concepts fit neatly into the contexts of these units. Thus, there were lessons that were taught simply as mathematics lessons or science lessons, with integration not immediately possible, if at all. Nonetheless, the two curricula were taught with as much integration as was possible considering the limitations that are inevitable in the combining of two preexisting curricula. The fundamentals of linear relationships and number sense and algebra were reinforced throughout the course, as were the problem-solving processes and strategies common to science and mathematics. Strategies to improve literacy were also evident throughout the course, as were activities to promote inclusion and positive group interactions. It was believed that these contribute positively to student success in all subject areas and could not be left out of any science and mathematics program.

In both the treatment and control groups, the attitudinal surveys were given twice, as early as was convenient and possible during the first week of classes for the course and as late as was convenient and possible during the last week of classes for the course. Some flexibility in timing was necessary since the investigation relied on the co-operation and assistance of many teachers to ensure complete data collection. The

surveys were accompanied by a brief script that the teachers who were administering them used to remind students of the purpose of the surveys and to give basic instructions on how to complete them correctly. Students in the treatment group completed both the science and mathematics surveys at the same time, while students in the control group completed the science portion in their science class and the mathematics portion in their mathematics class. Due to the fact that the principal investigator was teaching while many of the other classes were taking place, it was necessary for the researcher to rely on the other teachers to conduct surveys.

### **Methodological Assumptions**

Several assumptions were made during the course of this research. One assumption was that all teachers involved in teaching the grade 9 academic science and mathematics program would be covering the expectations outlined in the curriculum documents in the manner required by the Ministry of Education for Ontario. In addition, it was assumed that the teachers would administer and grade the final assessments in a similar fashion.

A second assumption was that the scheduling and location of the classes during the day would not impact on the student attitude or performance. The treatment group classes were both conducted in the morning, before lunch, while the control group classes were conducted in both morning and afternoon timeslots. The treatment group classes had science and mathematics in the same classroom, while the control group classes had science and mathematics in two different classrooms. It was assumed that having mathematics in a science classroom did not have any impact on student learning or attitude.

### **Limitations**

Several threats to internal validity were present in this research. The first source of threat was from the selection of participants. Students could not be randomly assigned to the treatment group from the entire grade 9 population. Students had to first obtain signed parental consent. Students who were selected to be in the integrated classes may have been sorted according to parental involvement in school life and the degree of influence parents had in student decision-making around course selection. Further to this, it was more likely that parents and students with a positive attitude toward science and mathematics would engage in the program. This attitude may have affected student achievement.

A second source of threat was from the history effect of the treatment group compared to the control group. Students in the treatment group had the experience of watching other students completing their studies in mathematics and science in half the time while they continued on. While their science and mathematics classes lasted all year, some of their friends wrote exams and finished the course in February. This may have been frustrating to students in the treatment group, especially to students who do not enjoy mathematics or science, and in turn could have affected their attitude and achievement. A related threat is that of resentful demoralization in the control group. Students in the control group may be hostile towards the students in the treatment group as they are perceived as getting extra attention or special privileges. Some students in the control group may have been very disappointed at not being selected into the treatment group. Students in the control group may have seen the surveys as an opportunity to

undermine the research and may not have completed the surveys as carefully or accurately as was possible.

A third source of threat comes from the maturation of the students in the treatment group compared to the control group. The treatment group had a full year to learn the material and consolidate their understanding. Exposure to the concepts over a prolonged period of time may have impacted their achievement. Since students in the treatment group had both science and math for a 10-month period instead of 5 months that the control group experienced, fatigue with the program may have affected the attitude of the treatment group towards both mathematics and science.

The final source of threat to internal validity comes from experimenter bias. The teacher of the treatment group was also the researcher and as such may have been more highly motivated when planning and teaching lessons. Some of the data that were collected were teacher-marked and more subjective in nature. Although the EQAO and the final science exam were conducted in a highly controlled and uniform manner, the final performance assessment tasks were not carried out in the same manner. These assessment tasks were carried out during regular class time by the classroom teacher. Although teachers tried to ensure uniformity in the procedures used, variations in instructions and timing sometimes occurred. All teachers involved in teaching grade 9 science or mathematics worked together to develop common marking schemes and to establish common standards to use while grading student work. Although some variations in assessment may have existed, they should have been significantly reduced by this effort. Finally, because the researcher was a teacher for most of the day, she was unavailable to conduct the surveys and present information to the regular grade 9 science

and mathematics classes. This variation in how the surveys were conducted may have had an impact, although an information and instruction sheet was provided for teachers to read to their class when they were completing the surveys.

A limitation of this research was the difference in timetabling between the treatment and control groups. The treatment group had science and mathematics taught throughout the entire year, whereas the control group had a single semester during which each course of study was completed. A semester is defined as one half of the school year at the secondary school level. Semester 1 began in September and ended at the beginning of February. Semester 2 began in February and ended at the end of June. As well, in the control group some students studied science and mathematics concurrently while others had the subjects scheduled consecutively. Among the consecutive group, some had science first followed by mathematics, while others had mathematics followed by science. This limitation was a consequence of the organization of the school and was difficult to overcome during the planning of this research. The decision to run the integrated program for the treatment group over an entire year as opposed to within a single semester in order to facilitate school scheduling was made by administration and leadership team members, which includes the principal, vice-principals, and department heads. This limitation was unavoidable within the parameters of the investigation.

### **Ethical Considerations**

The research was conducted in a manner that did not in any way place students in the research at a disadvantage or at risk. The integrated program would have been pilot-tested regardless of whether or not this research took place, and participation in the integrated program was completely voluntary and based on an informed decision. It is

possible that students in the integrated program experienced some benefits over their peers. In the integrated program, students had the opportunity to explore the science and mathematics curricula in a manner that may have been beneficial to them. The concepts were taught in a unit context that was based on relevant and current topics and issues and thus were more engaging and motivating to some students. Students had a full school year to cover the science and mathematics curricula, instead of a single semester, and may have found that this longer timeframe allowed increased opportunities to revisit concepts and increase learning. The students had the same teacher all year, which may have reduced some of the stress and confusion around a rotary timetable, particularly for students who had not experienced this type of schedule in their elementary schools.

Students may have developed increased confidence and an improved attitude toward their abilities in science and mathematics and be subsequently more highly motivated to continue their studies in these areas. Decisions around career selection may have been similarly affected. Students remaining in the regular program were not put at any disadvantage for the purposes of this research, as they experienced the typical program offered at Midtown Secondary School without any changes that could adversely affect their grade 9 science and mathematics experience.

All students in the control group and the treatment group were able to participate in the research on a voluntary basis. A letter of invitation was sent home to eligible students at the beginning of the school year outlining the scope and purpose of the research, and informed consent was obtained from all participants. Student who elected to not participate were not treated in any way that would have been construed as punitive or embarrassing. Nonparticipating students completed all surveys along with their

classmates, but those surveys were not used in the tabulation of data for the purposes of the investigation. All students completed the final assessment tasks as would normally have occurred in the absence of this research study. Both control group and treatment group students received identical consideration in terms of the administration and assessment of their final evaluation pieces.

The principal investigator was also the sole teacher of the treatment group. Although this introduced bias into the investigation, it was not a bias that in any way negatively impacted the success or attitude of the treatment group. While the investigator may have unintentionally influenced results of the study, the influence was likely only a positive pressure to succeed in and enjoy the integrated instruction. While not ideal from the point of view of conducting a completely fair investigation, it was not detrimental to the subjects in the treatment group.

This research contributed to further understanding of the efficacy of integrated programming in science and mathematics. The literature suggests that there is an insufficient number of qualitative studies to support the hypothesis that integration improves success and attitude. This research also provided evidence to support the continued development and expansion of integrated science and mathematics programming both at Midtown Secondary School and, potentially, at other schools in the Suburban District School Board.

This study was reviewed and given clearance by the Brock Research Ethics Board on August 31, 2005 (see Appendix C).



## **CHAPTER FOUR: PRESENTATION OF RESULTS**

The purpose of this research was to explore two questions: (a) Does the integrated approach to science and mathematics instruction have any impact on the achievement of students in the integrated class compared to those in a traditional setting, and (b) Are there any notable differences in attitude toward either subject area for students in the integrated class? In this quasi-experimental design, both the treatment and control group students received instruction using the expectations of the grade 9 academic science and mathematics curricula. The two groups were exposed to different instructional strategies; the treatment group experienced the science and mathematics curricula from a single teacher in an integrated fashion, and the control group had a more traditional approach with separate science and mathematics teachers and classrooms. Achievement was compared through four different measures. Student performance on the Education Quality and Accountability Office (EQAO) grade 9 mathematics assessment was used to compare the treatment and control groups. In addition, science exam results and the science and mathematics final assessment task were used to compare achievement. Attitudinal data were collected from surveys completed by treatment and control group students at the beginning and the end of both the science and mathematics courses.

### **Findings**

The achievement and attitude data are described and analyzed in this section. The data allow for comparisons between the treatment and control groups on measures of science and mathematics achievement and on changes in the participants' attitude towards science and mathematics from the beginning to the end of the study. Grade 6 and grade 9 EQAO results were analyzed using an analysis of covariance, where the

independent variable was the nature of instruction received and the covariate was the grade 6 EQAO scores. The math final performance assessment task, the science final performance assessment task, and the science exam were all compared using a one-sample *t* test. Question 1a of the attitude survey was analyzed using the Mann-Whitney *U* test. Remaining survey questions were clustered into three different groups, each one representing a different indicator of attitude. Questions 1b through 6 measured student perceptions of science or math, questions 7 through 10 measured motivation and students' confidence in their own abilities in science or math, and questions 11 through 13 measured the students' perception of the quality of their classroom experience in science or mathematics. Each response was given a value, with 1 being the answer indicative of a less positive attitude, and 3 being the answer indicative of a more positive attitude. For questions 1b through 5, 7, 12, and 13, the responses *disagree* or *not important* were given a value of 1, and the *strongly agree* and *very important* responses were given a value of 3. This was reversed with questions 6 and 8 through 11 to reflect that in these cases the response most indicative of a positive attitude was the one that disagreed with the statements. Total scores were obtained for each cluster of questions and then analyzed using an analysis of covariance, with the nature of the program being the independent variable and the precourse survey responses being the covariate.

#### *Achievement Results for Treatment and Control Groups in Mathematics*

Data were collected in an effort to measure and analyze student achievement. Among the data collected were the grade 9 EQAO math results as published by the EQAO office in October of 2006. The tests were administered to all mathematics students in a standardized fashion and reflect the most unbiased assessment instrument available

in this study since it was not graded by any teachers in the school. The EQAO scores are used as exam marks by Midtown Secondary School to eliminate the need for students to write two separate summative paper-and-pencil math assessment measures. Thus, although written outside the regular exam schedule and in a format different from typical school exams, the EQAO is now considered to be the grade 9 mathematics exam, with a complement of multiple choice, short-answer and long answer questions. In addition to the 2006 data, scores were available for the same cohort of students from their grade 6 EQAO mathematics assessment. Using both sets of data allowed for an analysis of covariance to determine whether the nature of the instruction the students received had, in fact, any impact on their mathematics achievement. One drawback to the use of these data was the lack of precision of the reporting. Scores were available only as whole numbers between 1 and 4. This limits the accuracy of the data.

The results of the analysis shows that there was no statistically significant effect of treatment on grade 9 EQAO scores after controlling for the effect of grade 6 EQAO scores,  $F(1,86) = 2.219, p = .140$  (see Table 2). Means and standard deviations for grade 6 and grade 9 EQAO tests are reported in Table 3.

The second instrument used to measure achievement in mathematics was the final mathematics summative task. This assessment focused more on open-ended problems which required students to draw on their inquiry skills in order to be successful. This assessment piece was teacher-developed within the school and was assessed with teacher collaboration. Teachers made sure they had a shared and agreed upon understanding of the evaluation rubric. The data were analyzed using a one-sample  $t$  test. The treatment

Table 2

*Analysis of Covariance for Grade 9 EQAO Mathematics Scores*

Source	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
EQAO – Gr. 6	1	.043	.043	.224	.638
Group	1	.429	.429	2.219	.140
Error	86	16.605	.193		
Total	89	742.000			

Table 3

*Grade 6 EQAO and Grade 9 EQAO Mathematics Mean Scores and Standard Deviations  
as a Function of Type of Program*

Program	<u>Grade 6</u>			<u>Grade 9</u>		
	<u>N</u>	<u>M</u>	<u>SD</u>	<u>N</u>	<u>M</u>	<u>SD</u>
Regular	40	2.60	.63	54	2.78	.50
Integrated	49	2.69	.58	54	2.91	.35

group ( $M = 72.50$ ,  $SD = 13.45$ ) scored significantly higher than the control group, ( $M = 64.44$ ,  $SD = 21.07$ ),  $t(54) = 2.37$ ,  $p = .02$ .

#### *Achievement Results for Treatment and Control Groups in Science*

The instruments used to measure achievement in science correspond roughly to those used in mathematics. The science exam, although not standardized across the province, was nonetheless developed and graded in the same manner by all grade 9 teachers in the school. The nature of the questions (e.g., multiple choice, matching, labelling diagrams) leaves little room for interpretation of answers. The exam is meant to measure strictly knowledge expectations from the science curricula as inquiry expectations are evaluated through the final performance assessment task. The data were analysed using a  $t$  test. The treatment group ( $M = 74.89$ ,  $SD = 11.08$ ) scored significantly higher than the control group, ( $M = 70.09$ ,  $SD = 13.24$ ),  $t(54) = 2.03$ ,  $p = .045$ .

Finally, the final science summative assessment task was the last measure of achievement that was used to compare the treatment and control group. At this school, the grade 9 science final summative evaluation is based on lab skills and requires the students to correctly use microscopes, multimeters, and chemical tests to carry out a series of tasks. Students were graded on how well they used the equipment to measure and observe as well as the quality of their observations and conclusions. Thus, although this corresponds to the math final summative task in a sense, it is actually quite different in that the inquiry skills being assessed are more practical and hands-on and are less focused on problem solving. The results for the science final summative task were collected and subjected to a  $t$  test. Analysis showed that there was no significant

difference between the treatment group ( $M = 70.81$ ,  $SD = 11.18$ ) and the control group, ( $M = 72.23$ ,  $SD = 16.33$ ),  $t(54) = .52$ ,  $p = .60$ .

#### *Attitude Results of Treatment and Control Groups for Question 1a*

The first question on the attitude survey was intended to measure student expectations as to whether they would eventually work in a field that required education in either science or mathematics. This question required only a *yes* or *no* answer. The data were tabulated and responses were assigned a value (1 = *no*, 2 = *yes*), and then a Mann-Whitney  $U$  test was performed on each data set, pre- and postsurvey for both science and mathematics. Before the intervention using an integrated science and mathematics program, there was a significant difference favouring the students in the treatment group for their expectations that they would work in fields that use math ( $U = 970.50$ ,  $N_1 = 51$ ,  $N_2 = 51$ ,  $p = .037$ , one-tailed). However, by the end of the program there was no significant difference between the two groups ( $U = 1018.50$ ,  $N_1 = 51$ ,  $N_2 = 51$ ,  $p = .786$ , two-tailed). Before the intervention using an integrated science and mathematics program, there was no significant difference favouring the students in the treatment group for their expectations that they would work in fields that use science ( $U = 1093.00$ ,  $N_1 = 51$ ,  $N_2 = 51$ ,  $p = .950$ , two-tailed). At the end of the program there was still no significant difference between the two groups ( $U = 919.50$ ,  $N_1 = 51$ ,  $N_2 = 51$ ,  $p = .166$ , two-tailed).

#### *Attitude Results of Treatment and Control Groups for Questions Relating to Student Perceptions of, Motivation in, and Quality of Classroom Experience in Mathematics or Science*

The remainder of the attitude analysis was conducted according to several categories thought to influence student learning, as outlined in the School Achievement

Indicators Program (1999). Attitude was measured using a 3-point Likert scale, and the responses were tabulated with the most positive responses being assigned a value of 3 points and the most negative attitude assigned a value of 1. An analysis of covariance was conducted to determine whether any differences in attitude could be attributed to whether the course was taught in a traditional or integrated manner after controlling for the effect of pretest scores on the same survey.

Questions 1b through 6 on the survey asked questions intended to measure the student perceptions of school and science or mathematics. These questions examine students' attitudes and beliefs about the importance of science and mathematics and how important they perceive these subjects to be to their parents and teachers. The results of the analysis show that in mathematics there was no statistically significant effect on student perceptions of mathematics importance after controlling for the effect of presurvey scores,  $F(1,99) = .374, p = .542$  (see Table 4). The results of the analysis in science shows that there was no statistically significant effect on student perceptions of science importance after controlling for the effect of presurvey scores,  $F(1,94) = .000, p = .989$  (see Table 4).

Questions 7 through 10 on the survey asked questions intended to measure student motivation in science and mathematics and student attributions of failure or success in science or mathematics. These questions examine how persistent a student would be in the face of difficulty in either subject area and to what factors students attribute their success or failure in science and mathematics. The results of the analysis show that in mathematics there was no statistically significant effect on student perceptions of mathematics motivation after controlling for the effect of presurvey scores,  $F(1,95) =$



.078,  $p = .781$  (see Table 4). Students in the treatment group answered the questions in a manner that would suggest that they are not more likely to persist when they encounter a challenge in mathematics and do not have a more positive attitude towards their achievement in mathematics. The results of the analysis show that in science there was also no statistically significant effect on student perceptions of science motivation after controlling for the effect of presurvey scores,  $F(1,94) = .074$ ,  $p = .787$  (see Table 4). Students in the treatment group answered the questions in a way that would suggest that they are not more likely to persist when they encounter a challenge in science and do not have a more positive attitude towards their achievement in science.

Questions 11 through 13 on the survey asked questions that were intended to measure student attitude towards the quality of their classroom experiences in science or mathematics. These questions examined how students felt about their experiences in science and mathematics. The results of the analysis show that in mathematics there was no statistically significant effect on student perceptions of the quality of their classroom experiences after controlling for the effect of presurvey scores,  $F(1,98) = .798$ ,  $p = .374$  (see Table 4). Students in the treatment group did not have a more positive attitude toward the quality of their mathematics classroom experience. The results of the analysis show that in science there was no statistically significant effect on student perceptions of the quality of their classroom experiences after controlling for the effect of presurvey scores,  $F(1,94) = .042$ ,  $p = .837$  (see Table 4). Students in the treatment group did not have a more positive attitude toward the quality of their science classroom experience.

Means and standard deviations for the scores on the attitude scale are reported in Table 5.

Table 4

*Analysis of Covariance Source Table for Survey Scores*

Source	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Presurvey science perceptions	1	3.386	3.386	38.532	.000
Group	1	.000017	.000017	.000	.989
Error	94	8.260	.088		
Total	97	531.250			
Presurvey math perceptions	1	2.125	2.125	18.592	.000
Group	1	.043	.043	.374	.542
Error	99	11.315	.114		
Total	102	647.194			
Presurvey science motivation	1	9.941	9.941	66.558	.000
Group	1	.011	.011	.074	.787
Error	94	14.039	.149		
Total	97	488.250			
Presurvey math motivation	1	10.898	10.898	64.137	.000
Group	1	.013	.013	.078	.781
Error	95	16.142	.170		
Total	98	499.750			

*(table continues)*

Source	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Presurvey Science Quality	1	5.586	5.586	19.189	.000
Group	1	.012	.012	.042	.837
Error	94	27.361	.291		
Total	97	393.111			
Presurvey Math Quality	1	8.402	8.402	39.602	.000
Group	1	.169	.169	.798	.374
Error	98	20.792	.212		
Total	101	404.667			

Table 5

*Pre- and Post- Survey Mean Scores and Standard Deviations as a Function of Instruction**Condition*

Source	<u>N</u>	Presurvey <u>M</u>	<u>SD</u>	<u>N</u>	Postsurvey <u>M</u>	<u>SD</u>
Science						
Quality						
Treatment	53	2.21	.51	50	2.02	.72
Control	50	1.85	.45	47	1.82	.41
Perception						
Treatment	51	2.39	.33	48	2.30	.33
Control	50	2.41	.37	49	2.33	.37
Motivation						
Treatment	53	2.54	.31	51	2.40	.41
Control	49	1.92	.61	46	1.93	.59
Mathematics						
Quality						
Treatment	52	2.21	.50	50	1.98	.57
Control	53	1.86	.50	51	1.88	.51
Perception						
Treatment	53	2.62	.29	51	2.56	.33
Control	53	2.43	.36	51	2.43	.40
Motivation						
Treatment	53	2.51	.36	51	2.36	.42
Control	50	1.91	.61	47	2.00	.63

## **Implications**

The results of the data analysis have several implications for mathematics and science. In mathematics, there was no significant difference found between the EQAO scores of the treatment and control groups. This suggests that either the integrated program did not significantly impact on the learning of the mathematical concepts assessed in the EQAO or that the EQAO assessment did not capture the improvements in learning that the integrated program provided to the treatment group participants. The second measure of achievement in mathematics was the final assessment task. In this case the treatment group did perform significantly better than the control group. This would suggest that the integrated program did have a positive impact on the students' skills in answering more open-ended, problem-based questions. It also could imply that more open-ended questions better allow students to demonstrate the skills and learning they have improved through participation in an integrated program.

In science, the first measure of achievement was the science exam. In this case the treatment group scored significantly higher than the control group. This implies that participation in the integrated program provided some benefit to either their learning of science or their ability to respond correctly to test- and exam-type questions. Analysis of the final science summative task did not illuminate any significant difference between the treatment and control groups. Apparently the laboratory experiences and hands-on tasks provided in the integrated program compared to the regular program did not provide any benefit or impediment to the treatment group.

The first question of the survey asked students about their expectation to work in a field that required education in science or math. Initially, the results show that the

treatment group had a greater expectation to use math than the control group. No such difference existed between the treatment and control groups when initially surveyed about their expectations to work in a field that required science. By the end of the science or math course, both groups had equal expectations. This suggests that students in the treatment group had different expectations about their future education and career choices with respect to math, but that both the treatment and control groups shared similar expectations when it came to science. It also implies that participation in the integrated program did not alter these expectations in science relative to the control group but did reduce the expectation to work in a field that required education in mathematics.

The remainder of the survey was clustered into three different groups of questions. The three clusters were meant to capture different indicators of attitude. The first considered student perceptions of science or mathematics, the second cluster focused on student motivation and confidence, and the third cluster determined student perceptions about the quality of their science or mathematics classroom experience. In each cluster, a higher score can be interpreted as an indicator of a more positive attitude toward mathematics or science. In all three clusters of questions, the treatment group showed no statistically significant increase in score relative to the control group following completion of the science or mathematics course. This indicates that participation in the integrated program had little or no impact on the attitudes of the treatment group as compared to the students receiving the regular mathematics and science programs in the control group.

## Summary

In summary, then, it is accurate to say that there were some significant differences detected between the achievement of students in the treatment group versus the control group. In the case of the mathematics there were two measures, the EQAO assessment and the mathematics final assessment task. After controlling for the effect of grade 6 EQAO scores, no significant difference in achievement was found between the treatment and control groups. The mathematics final summative task was the second measure used to compare the treatment and control groups in mathematics. In this measure, a significant and substantial difference was found between the treatment and control groups, with the treatment group performing more successfully than the control group. The results in science are also based on two different assessments. The first was the science exam, and with this measure the treatment group scored significantly higher than the control group. The second was the science final performance assessment task. In this measure no significant difference was found between the treatment and control groups.

The attitude survey indicates that there were no statistically significant differences between the treatment and control groups in terms of their expectations for using mathematics and science in the future, their perceptions of science or mathematics, their motivation and confidence in science or mathematics, and their perception of the quality of their experience in the science or mathematics classroom. According to the results from Question 1a, students in the treatment group started off with a higher expectation than students in the control group that they would work in fields that require mathematics education. By the end of the course, there was no statistically significant difference between the treatment and control groups in this regard. They had similar expectations in

this regard. In science, there was no significant difference detected either pre- or postsurvey that would suggest the treatment group had any different expectations of working in fields that require education in science compared to the control group.

In the questions that measured student perceptions of school science or mathematics there was no statistically significant difference noted for the treatment group after controlling for pretreatment scores in science and in mathematics. Similarly, students in the treatment group demonstrated no statistically significant difference in response to the questions relating to motivation and confidence in science and mathematics. Finally, an examination of the results intended to measure student perception of the quality of their classroom experience shows that in both science and mathematics students in the treatment group demonstrated no statistically significant response when compared to their counterparts in the control group.

The implications of these results for practice, for theory, and for further research will be discussed in detail in Chapter Five.



## **CHAPTER FIVE: SUMMARY, DISCUSSION, AND IMPLICATIONS**

Science and mathematics education are subject areas held in high esteem in modern society. Providing proper education in both is seen as necessary to ensure the success and security of a modern society (Black & Atkin, 1996). Parents view science and math as critical elements in ensuring their child's success in an increasingly technological and information-driven economy. International testing serves to rate and compare performances among countries, and anything but a high ranking in science or math usually results in calls for reform in education and revision of educational curricula. Like the proverbial canary in a coal mine, performance in science and math is often viewed as a significant sign of the health of an education system and indicator of the potential of Canadian society to succeed (Council of Ministers of Education, Canada, 2003).

Renewed efforts to revise science and mathematics education can create unintended outcomes. The release of more rigorous science and mathematics curricula in Ontario in 1999 was meant to ensure a more scientifically and mathematically literate graduate. Some felt that the good intentions were outweighed by the fact that the curricula were too broad and placed unreasonable demands on secondary school students. This was confirmed when an alarming decrease in credit accumulation began to occur and graduation rates began to fall (King, 2003). Despite the good intentions, efforts to improve performance in science and mathematics did not provide the anticipated rewards.

Attitudes towards science and mathematics are a concern as well. Indications from the statistics provided by the guidance department suggest that only a relatively small proportion of students at Midtown Secondary School, a typical school in the

Suburban District School Board, are selecting science and mathematics courses at the senior level. Although students are informed about the importance of science and mathematics courses in allowing them to have a full range of career options, they are nonetheless opting out of those courses in discouragingly high numbers. Just as the performance of students is an issue to consider, so too is their lack of consideration of science and mathematics as vital options when career planning.

One possible solution for improving performance and attitude in science and mathematics is that of integration. Beane (1995) argued that integration allows students to approach science and mathematics from a viewpoint based in the “problems, issues, and concerns posed by life itself” (p. 616) and that, in fact, “curriculum integration is the search for self and social meaning” (p. 616). As Berlin and White (1994) suggest, “Teachers need to help their students become aware of meaningful, positive examples of science and mathematics integration that relate to their lives now and in the future” (p. 2). They suggest that this speaks to the goal of increasing the likelihood of students pursuing careers related to science and mathematics. The overlap of expectations would allow for increased opportunities to practice skills and consolidate understanding. According to Wells (2004), through the implementation of an integrated science and mathematics curriculum, assessment and evaluation could become a more authentic and meaningful experience for students. Such assessment practice would allow teachers greater insight into what their students know and can do.

The purpose of this study was to investigate the impact of an integrated grade 9 science and mathematics curriculum on attitude and performance of grade 9 academic level students. In order to accomplish this, a program was developed that allowed as

much integration as possible between the two subjects while maintaining the integrity and intentions of the Ontario curriculum. The course was taught for one full school year, with one period per day devoted to it on the students' timetable. Students and their parents were informed about the program while the students were in grade 8, and those students and their parents who were interested in participating submitted a request to take part in the integrated class. Fifty-four students were randomly selected from an unknown number of submitted requests and organized into two classes comprising the treatment group. A similarly random sample of 54 students was selected from the regular, nonintegrated classes. These students served as the control group to which the integrated students could be compared. Both the treatment and control groups were surveyed to establish their attitudes towards both science and mathematics. In addition, data were collected from both groups to establish their performance on a variety of assessment tasks including the EQAO math assessment, exams, and final performance assessment tasks.

### **Summary of the Study**

The first requirement of this study was the development and implementation of a full year integrated course in grade 9 academic science and mathematics. Several models for integration were considered while developing the grade 9 integrated science and mathematics program. The program was necessarily driven by the requirements of the science and mathematics curricula as mandated by the Ontario Ministry of Education, and thus limited the amount and nature of the integration that could take place. The resulting design could be considered partially integrated, according to the continuum of curriculum design outlined by Hurley (2001). This means science and mathematics were taught as separate subjects at some points and were blended together at others. The

program ended up drawing upon several of the aspects given by the Berlin-White Integrated Science and Mathematics Model (1994). Specifically, learning was organized around the methods of inquiry found in both science and mathematics as well as around content and thinking skills that overlapped the two disciplines. In addition, the teaching strategies were selected that “assist students in bridging the gap between math and science” (Berlin & White, 1994). The resulting course was implemented as a full-year course, with students having one period a day with the same teacher in the same classroom. There was no set schedule as to when science or mathematics would be taught; the program flowed from the organization of the units as outlined in Appendix D.

In order to compare the attitude and achievement of students in the integrated and regular science and mathematics classrooms, several data sets were collected. All efforts were made to ensure that the assessment tasks used were administered and evaluated with consistency. The treatment and control groups were compared in terms of attitude towards science and mathematics. To measure attitude, a total of four surveys were done for each student. A survey for each of science and mathematics was conducted at the beginning of each course, and identical surveys were administered again at the end of each course. The surveys were designed to measure the expectations that students had about needing science or mathematics education in their future careers, their perceptions of school and science or mathematics, the motivations and attributions of the students to their own success, and their feelings about their science and mathematics classes. The surveys allowed for a comparison between pretreatment and posttreatment attitudes to see whether any significant attitude changes occurred in the treatment group as compared to the control group.

In addition to attitude, achievement on several academic measures was used to provide insight into the effects of the integration. The EQAO mathematics test results were used, since they are considered to be a reliable measure of mathematics achievement. The following measures from within the school were also used: the science examination results, the mathematics final performance assessment task results, and the science final performance assessment task results. All students were given identical or highly similar tasks and examinations in these cases, and teachers assessed student work according to an agreed upon marking scheme. These measures were also compared to see if there was any significant difference between the treatment and control groups in terms of achievement.

The results of the study suggested that the integration does, in fact, have some impact on achievement in science and mathematics. The attitude survey showed that attitude towards science and mathematics was not improved through participation in the integrated science and mathematics program. This is contrary to findings such as those by Singh, Granville, and Dika (2002), who found that science and mathematics achievement were significantly influenced by motivation and attitude of students. Singh et al. postulated that “students’ motivation to learn mathematics and science can be increased and improved when teachers create a curriculum that focuses on conceptualizing and creating meaning and relevance” (p. 330). It could be argued that any increase in achievement in science and mathematics is not due directly to the nature of the instruction in an integrated course but rather is a by-product of an improved motivation and attitude formed by a more engaging program. However, in the example provided by

this research the evidence suggests that improved achievement was not due to any improvements in attitude or engagement as measured by the survey results.

In the area of motivation and attribution of success, there was no statistically significant difference between the treatment and control groups. Students in the treatment group did not have any change in attitude toward their own performance in science and mathematics as a result of participation in the integrated program. This is contrary to Berlin and White's (1994) suggestion that participation in an integrated science and mathematics program allows students to better see themselves as capable of success in either subject area. House (2006) found that students who attributed success to hard work were more likely to earn higher scores in mathematics testing. If students indicated that they thought mathematics was boring and that doing well in mathematics was dependent on natural ability or good luck, they did not score as well on mathematics testing. Thus, a change in a student's attributions of success could be an important prerequisite for improved achievement. This was apparently not the case in this study, as the treatment group experienced improvements in achievement despite the lack of any significant improvement in motivation and attribution of success.

Students in the treatment group had the same attitude toward the quality of their classroom experience for both science and mathematics as their counterparts in the control group. It was anticipated that students may have found the learning experience in the integrated program to be novel and have been appreciative of the unique context into which the curriculum was placed. Any such response to the integrated program was not reflected in either an improved interest in the subject or a more positive attitude towards the day-to-day operation of the classroom. It was also possible that the students in the

treatment group felt some degree of privilege in being selected to participate in the integrated program and subsequently viewed their experiences more favourable as a result. Again, if this was indeed the case, it did not result in any favourable changes in attitude for the treatment group.

The only survey result that showed a significant difference between the treatment and control groups was the expectation that students had about needing science or mathematics education in their future careers. The data indicate that students in the integrated program had a reduced expectation that they would use mathematics, but in science they remained on par with their nonintegrated peers. Berlin and White (1994) maintained that integration of the two subjects allows students to see connections between the two and would thus enable them to see the purpose and usefulness of both. However, being able to see how and why something is important does not necessarily translate into seeing the use of it personally. Indeed, this insight into the usefulness and purpose of mathematics may convince some students that, although they understand why math is important, they would rather not make it a part of their aspirations. Singh et al. (2002) argued that by the time students reach high school they have already decided whether or not they will pursue courses of study that include science and mathematics. If this is true, then perhaps a single year of integration in grade 9 is too little and too late to seriously impact students' career choices.

An analysis of the measures of achievement indicated that some benefit was gained by the students in the integrated program in their inquiry skills in mathematics. The final summative grades were significantly higher for the integrated group than for the

nonintegrated. Interestingly, the science summative scores between the treatment group and the control group did not show any statistically significant difference.

### **Discussion**

The achievement data were collected from two different categories of assessment. The first was the more traditional pencil-and-paper short-answer exam. This was represented by the final science exam and by the EQAO mathematics test. In both of these measures the treatment group did not show any significant difference from the control group. Considering that students in the integrated class had considerably longer periods of time during which to learn the material and more frequent opportunities to review and apply it, this was surprising. Perhaps the issue lies with the method of assessment rather than the instruction. The students who were being taught science and mathematics in an integrated fashion had to then dissociate that information in order to write separate exams for science and mathematics. A more authentic reflection of their knowledge may have come from a test that assessed the knowledge in the same manner in which the students learned it, in a realistic context that relied on both disciplines. Unfortunately, the Ontario Ministry of Education requires that separate grades be given for science and mathematics, which therefore necessitated such distinct evaluations. The demands of this research project also required consistent final evaluation between the two groups.

The results of the final mathematics summative task were a different story. In this measure, the treatment group did score significantly higher than the control group. It is important to realize that the final mathematics summative task placed a much greater focus on inquiry and communication than did the EQAO test. Since the basic inquiry



skills are very similar between science and mathematics, the students had plentiful opportunities to develop these skills, since they were used for both subjects. Also, much of the curricula was presented as contextually embedded problems that required science and mathematics knowledge and inquiry skills to solve. Thus, such scenario-based, open-ended questions as were posed in the final mathematics summative task would have been very familiar. Some discussion and group work were allowed, a strategy with which the students were also very comfortable. In other words, the mathematics summative task was a better reflection of the teaching and learning that went on in the integrated class than were the exam and the EQAO assessment.

In light of the good results for the mathematics summative task, why then did the results for the corresponding science summative task not reflect an improvement in results for the treatment group over the control group? Again, a consideration of the nature of this evaluation provides key insights. The science summative was also assessing inquiry, particularly the skill of observation and the ability to write and explain a conclusion based on evidence. In order to collect the evidence, students had to use equipment, such as a microscope or multimeter, that students in the treatment group may not have had opportunity to use in quite some time. Despite opportunities to review a technique at lunchtime, most students in the treatment group were out of practice when they actually completed the tasks that had been assigned. The situation was somewhat similar in the control group, but those students had learned and practiced the required skills over a single semester as opposed to over an entire school year. This may have negatively affected the confidence and comfort level of students in the integrated program as they approached the tasks. Also, the summative task was carried out with

students in isolation, without any opportunity for discussion and input from their peers. The task was unrelated to any meaningful context. This would have happened rarely during lab work in the integrated program and, again, created an artificial environment very disconnected from what the students had experienced during their learning.

The attitude survey provided an interesting insight into whether the integrated program had an impact on the students in an affective rather than academic way. There was concern that the students in the integrated program would be very different from their counterparts in the regular program just because they had been interested in participating in such a program. Although it was initially presupposed that the typical integrated program student might have an affinity for both subject areas and would perhaps have a more positive attitude than his or her nonintegrated counterpart, this does not appear to be the case. In fact, there was an unexpectedly significant force at work in the application of students for the program: that of parental influence. Many parents viewed the program as a good opportunity to spark an interest in science and mathematics where little previous interest was evident. In some cases, parents indicated that their child's performance during elementary school had been relatively weak in the two subject areas. Parents hoped that the extra time for either science or mathematics, a full year instead of a single semester, would be beneficial. For numerous reasons, the integrated group was a much more diverse and realistic representation of a typical grade 9 class than was predicted initially.

The first question on the survey asked students, "When you are finished school some day, do you expect to work in a field that requires education in math (or science)?" The intention of the question was to determine whether students in the integrated

program had a greater sense of the pervasiveness of science and mathematics within the modern world and thus the workforce and would, as a result, be more apt to recognize the need for both science and mathematics education in order to prepare for future careers. This is not what happened. In the case of mathematics, the treatment group saw less of a need for mathematics than the control group did. There was no difference between students in the control group and the treatment group in terms of their attitude toward the need for science. It is possible that the wording of the question did not accurately capture its intention. A grade 9 student may read “do you expect to” as the same as “do you want to,” and those in the integrated class may have decided that they most certainly did not want to work in a field that requires mathematics once they had been exposed to the uses of mathematics in the real world. Students in the regular class, on the other hand, would not have had the same educational experiences and may not have been as quick to dismiss mathematics as part of their career plans. So, in a sense, the results can be considered positive, at least from a programmatic view, since it indicates that students in the integrated class may have been given a clearer view of the real-life potential of mathematics. The unfortunate negative result that must be examined is why this real-life view leads to mathematics being a less desirable part of students’ career planning. It was certainly not the intention of the program.

Another possibility is that while students in the treatment group saw that they would require an education in mathematics, it was really just a hoop through which they had to jump in order to pursue a career which, in reality, required very little use of mathematics. A point of discussion that came up at various points during the year was that, although mathematics was at the root of what a banker or an engineer might do

during a day, the banker and the engineer were not actually doing the mathematics, but a computer was. Many could cite examples from their parents' jobs. They seemed to distinguish between "doing" mathematics and merely "using" mathematics. In other words, mathematics is something that has been automated, while science still requires knowledge and a skill set that cannot be avoided. The survey results may reflect the fact that the students in the integrated program had given more thought than the average student about the role mathematics would play in their futures and had decided that technology would allow them to pursue technological and scientific fields without the need for mathematics.

The results of the survey questions which measured the perceptions of the students towards science and mathematics suggest that participation in the program did not have either a positive or negative impact on student attitudes. Students who opted to take the integrated course may have been more highly motivated in science and mathematics, and the two disciplines may have been valued more highly by both the students and their families. Thus, students may have selected the integrated program because they saw it as an opportunity to enrich their experiences in both courses and apply their understanding in new ways. Another possibility is that students and families who were more serious about studies in science and mathematics may have stayed away from the course for fear of getting less rigorous, even slightly frivolous learning experiences. Being the first year of a previously untested program at the school, the students in the integrated program had the strong sense of being "test subjects." It is possible that the composition of the class will change as the program is further established and develops a reputation for academic rigour.

Another area of the attitude survey that showed no significant difference between the treatment and control group was the questions that dealt with student feelings towards their classroom experience in science and mathematics. It was possible that students in the integrated program may have felt more fortunate in their classes as a result of being part of a group that was chosen to be part of a new educational initiative. Several students were very disappointed at not being chosen, and there was a sense initially that the integrated group was somehow privileged. This could have translated into a falsely positive attitude based more on belonging to a select group than on actual experiences in the classroom. However, a school year is a long time and provided plenty of opportunity for the novelty of the program to wear off for most students. The reality that the integrated program was really the same course taught in a different way was evident to the students as the year progressed. The perception that seemed to develop was that the integrated program was more rigorous than the regular program. Although the teacher was able to compare the courses directly and ensure that students in the integrated program were not being given a greater workload, students in the integrated program had no such gauge by which to measure their workload. As a result, some students in the integrated program ended up feeling as if they had endured a more challenging course. In addition, a sense of fatigue set in during the latter part of the year. Students saw some of their peers in the regular program finishing up science and mathematics courses in January, while the integrated course continued right to the end of the school year. Students who may not have been enthusiastic about science or mathematics to begin with were, to their way of thinking, being punished by even more science and mathematics than they would have otherwise had to endure. It is not surprising that, considering all of

these factors, the students in the treatment group did not have a significantly better attitude toward their experiences in the integrated classroom. It would be interesting to determine whether this attitude would be improved if all students participated in a full-year integrated program, thus eliminating some of the negative comparisons the treatment group may have made between the two programs.

Apart from the alternative program being offered, there were some other differences in how the treatment group experienced their science and mathematics classes compared to the control group. At times, these differences presented unexpected challenges to the teacher and were duly noted for future program adjustments. One of the most significant challenges arose from the thematic approach that was used in the integrated program. Because the thematic units were so large and encompassed so much content, they ended up lasting for a very long period of time. Although on a day-to-day basis the students were engaged and interested, eventually some students in the integrated group lost sight of the point of what they were learning or would wonder how much longer a unit would last. Initial excitement and curiosity were difficult to maintain for the extended period of time that these units required.

It is disappointing that a significant difference in attitude was not noted in the parts of the survey that centered on the students' improved sense of their own ability within the integrated program. These questions did not require students to consider the beliefs of others or to indirectly compare their experiences to their peers in other classes. These questions focused solely on how the students viewed themselves as learners in science and mathematics. The results suggest that students in the integrated program saw themselves as equally likely to rely on natural ability to do well and view luck or the

ability of the teacher as playing a part in their success. It was expected that the students in the treatment group would have a more solid grasp of the idea that their success in science and mathematics was largely related to their own efforts and willingness to persevere through challenges. As Berlin and White (1994) suggested, an increase in confidence may have resulted in the students seeing science and mathematics as subjects in which they are fully capable of participating. This is perhaps the most significant attitude change for which one could hope, as it speaks to a belief that can completely alter the manner with which a student approaches his or her own learning. If the students in the integrated program could carry on to grade 10 with the confidence that they themselves were the most important factor in determining future success, then a powerful shift will have occurred. For some students, that shift may be the difference between failure and success in future learning opportunities.

It is particularly important to try to explain why this measure of attitude was not influenced by participation in the integrated science and mathematics program, as it speaks so directly to the goals of education: to develop self-confident and self-directed learners. It was expected that the extra time afforded by the full-year integrated program gave students in the integrated program increased opportunities to revisit ideas and refine skills. Such an increase in opportunities to practice and review could have in turn increased confidence and competence in knowledge and skills. As Schmitt and Horton (2003) suggested, integration does allow for multiple opportunities to revisit concepts in a variety of contexts. A greater amount of time was spent focused on problem solving, with more time available for discussion than in the nonintegrated classroom. This should have allowed students to become more aware of what they actually knew and built

confidence in their own problem-solving abilities. Finally, if students viewed the integrated program as more rigorous, then the mere fact that they were successful in it might have given them a greater confidence in their own abilities. Perhaps a greater emphasis on personal reflection, through journaling, portfolios and discussion, might have allowed students to view their learning from a perspective that would have better encouraged a greater shift in attitude. Perhaps attitude change is a form of learning that requires coaching and feedback, just as changes in achievement do.

Parental support is important for a new program such as this, and so every effort was made to reassure parents that all learning expectations from both curricula were being addressed and that students were being evaluated in a manner similar to that which was taking place in a nonintegrated classroom. Parents were justifiably concerned that students in the integrated program would not be covering exactly the same curricular expectations and would not be assessed with the same rigour as their counterparts in the regular program. Efforts were made to address this concern and to ensure an organization of course materials and evaluation tasks that would be recognizable to parents.

Unfortunately, these efforts also resulted in obvious constraints in the structure and organization of the class. Tests were broken down to show which parts were science and which parts were mathematics. Unit summative tasks for science and mathematics were kept separate to ensure that distinct evidence of achievement was available for both subject areas. Notes were kept in binders divided by subject and further divided into units that matched the curriculum documents but did not necessarily make sense to the students. Thus, for example, although students may have had their work relating to the CSI unit, they were asked to put it into their binders in different sections (e.g.,



reproduction, matter, relationships, or algebra). Although such organization was successful in reassuring the parents of students in the untested and unproven integrated program, it also served to subtly undermine the premise of integration upon which the course was designed.

To imply that the entire year had involved successful integration of all expectations would be inaccurate. The curriculum itself served to limit what could be accomplished. Although suitable and meaningful connections could be found between science and mathematics, they did not always fit with the curricular expectations as outlined in Ministry documents. Conversely, some expectations simply could not be meaningfully and authentically integrated and required separate treatment to avoid trivialization for the sake of integration, as cautioned by Mason (1996). This diminished the intention of the integrated program. Even so, there were days when the students had to ask, “Is this math or science?” as the line between the two had blurred sufficiently so that the answer was not obvious, a fulfillment of the definition of integration offered by Lederman and Niess (1997). These were exciting moments, to realize that the class was doing something so interconnected that neither teacher nor student could identify definitively whether it was science or mathematics.

Attitudes of other teachers in the school towards the integrated program were, superficially at least, positive. Unless they were directly involved in gathering consent forms and data collection, most were unaware of what was actually happening in the integrated program. With few exceptions, teachers of the regular science and mathematics classrooms were helpful in gathering data and assisting with the paperwork that was required to conduct this study. Most were enthusiastically supportive of the

concept of integration and curious about the outcomes and implications of the research. On the other hand, some did find the structure of the integrated program within the school unsettling. Most science teachers would be able to teach grade 9 mathematics, but far fewer mathematics teachers would be comfortable or capable in a grade 9 science classroom. Thus, the fear of losing mathematics positions to science teachers was a concern. In addition, some teachers did not relish the idea of having a single class for an entire year, preferring a semestered schedule. Perhaps some uneasiness resulted from the fear that, if successful, this course might have become the way that science and mathematics was taught in the school and thus would require teachers to alter their timetables. Indeed, while integrating the curricula was a challenge, integrating the staff might present a much greater challenge. Resistance is subtle but emphatic. Discussion around the possibility of similar integration in grade 10 would be met with very different responses depending on who was participating in the conversation. The combining of science and mathematics was seen by some teachers as a loss of integrity of the mathematics curriculum, a genuine risk identified by Ross and Hogaboam-Gray (1996).

This research was unique in that the researcher was also the program designer and classroom teacher. This made the research personal and highly relevant, thus closely sharing characteristics of action research. Action research is a form of inquiry designed to attain the goal of improved classroom practice and student learning (Creswell, 2002), which was certainly amongst the goals of this endeavour. Creswell identifies one of the drawbacks of action research as being the time demands of simultaneously attempting to improve classroom practice while at the same time conducting research. This demand was certainly evident throughout this research. Creswell also notes that action research

does not require the same degree of rigour and the same precise and systematic approach as more formal academic research. The role of researcher was made all the more challenging by these requirements.

It was entirely, and perhaps naively, unexpected how significantly the demands of research would change the outlook and personal investment in the program for the primary researcher. While the development and testing of a new program was demanding, it was also exhilarating. There was much energy and excitement generated in the ability to create and deliver a new program. The decision to examine data to see whether the program had any effect on student attitude or achievement was important in order to lend credibility to the integrated program, but it also created a very different set of demands. It was very challenging to maintain objectivity while at the same time promoting and striving to make the integrated program work well for students. Knowing that the results could put the future of the program into question added a layer of stress to the process. Further to this, knowing that some teachers may have preferred that the program not demonstrate any appreciable differences in student learning created even greater demands, as it strained otherwise positive collegial relationships. Creating a program that challenged established and valued structures of how certain disciplines are delivered in a school involved a degree of personal and professional risk. Having the effectiveness of the program so publicly tested was, at the risk of making an understatement, difficult.

### **Implications**

The study has implications for both the classroom teacher and the researcher. Certainly the evidence suggests that there is reason to make an effort as a classroom

teacher to promote integration of mathematics and science. To the researcher, the study suggests that there are many more parameters to be explored in consideration of the impact of an integrated program. It also questions the value of a single definition of integration.

### *Implications for Practice*

The findings in the present study suggest that students may benefit from integrated instruction in science and mathematics. Although the results may not be evident in traditional measures of achievement, the data suggest that the gains will be evident in some elements of student attitude and in less traditional measures of success. The model of integration used for this program was not static. Different approaches were used depending on the content being covered and the needs of the students. Sometimes the class was fully integrated, and it was not apparent whether the students were doing science or mathematics. At other times, classes were devoted to a particular concept in science or mathematics without any attempt to integrate. In a situation where the curricula are set and cannot be altered, it is important that this flexibility be maintained. Since it would be extremely unlikely for a teacher to be able to select the curriculum that will be taught, flexibility is essential to ensure that the curricular expectations are covered appropriately while balancing this with the benefits of integration. Even small segments of integrated programming may be beneficial.

While the thematic approach to combining science and mathematics content was successful to a degree, it did create fairly lengthy units that may have encompassed too many learning expectations. A better approach would be to break these units into smaller segments and disperse them throughout the year rather than try to finish everything all at

once. Similarly, other smaller themes could be introduced that still allow for integration but do not cover the same large numbers of learning expectations. In fact, allowing for stand-alone lessons that are interesting on their own is perfectly legitimate and could reduce both teacher and student fatigue and maintain interest more readily. Not everything has to be taught within the context of a larger unit. Several models of integration do not actually rely on thematic approaches at all. The Berlin-White Integrated Science and Mathematics Model (Berlin and White, 1994), for example, provides for the integration of science and mathematics based on process and thinking skills rather than on topics or themes. Another possibility suggested by the Berlin-White Model is integration based on attitudes and perceptions towards science and mathematics. Davison and Miller (1995) offer similar alternatives with their idea of process integration, where the integration occurs through the use of common problem-solving strategies or through methodological integration, which allows for common learning strategies to link the science and mathematics together. The literature provides many alternative approaches to integration that could be used as an antidote to the lengthy and sometimes cumbersome thematic approach.

Although the students may have benefited from frequent repetition of mathematics concepts and skills, the science concepts did not seem to be reinforced as often. Again, if the units were broken up and staggered throughout the year, more opportunities to revisit and review a concept might occur. In addition, more frequent use of student-directed projects incorporating particular concepts and hands-on activities might provide greater opportunities for students to recall necessary facts and rehearse important lab skills.

Once an integrated science and mathematics program has been successfully established and has a record of success, it would be possible to break down some of the barriers to integration that existed initially. Challenges to student organization could be reduced if notebooks could be maintained and organized in a manner that better reflects the delivery of the course instead of forcing materials into categories that are illogical in the context of the integrated course. Similarly, assessment and evaluation could become better assimilated, with the teacher pulling evidence of learning out of blended tests and assignments rather than segregating the testing and assignments. Mason (1996) suggests that assessment itself must become interdisciplinary, blurring the boundaries between the traditional disciplines. This relies on the teacher having confidence in the assessment instruments that are being used and the parents having trust in the professional judgment of the teacher. Both take time to develop, so gradual change would be advised.

Although changes such as the ones mentioned in the previous paragraph would be positive, it is important to remember that parental support for the program was strong, and parents are important stakeholders in the success of an integrated program. Parents had valid concerns about equity and fairness with respect to the workload and stress that their children would experience compared to students in the regular program. Being mindful of these concerns is essential to maintaining parental support. Scheduling of tests, summative assessments, and final exams should be done with care to ensure that the students' workload is not perceived as overwhelming. Although students in the regular science and mathematics program could have potentially had equally demanding workloads, parents of students in the integrated program may be more sensitive to these

stresses and more likely to consider them a result of the integration rather than a natural part of the grade 9 program.

One significant challenge in developing and teaching an integrated program is finding the time to plan and refine the program and to improve practice. Bringing other teachers into the program allows a sharing of the workload and the injection of fresh points of view. According to Venville et al. (2000), such teachers must be committed to the planning and implementation of an integrated curriculum. They must feel highly confident and competent in the subjects they are teaching if they are to be an asset to the efforts to integrate. An integrated program places high demands on teachers and requires that common planning time is available and that there is full and ongoing support from the administration. An integrated program, like any good classroom program, cannot be planned for a year or two and then left to its own devices. It requires ongoing revision and reflection to ensure that it remains true to the original goals of the initiative and that it is meeting the needs of the students.

Finally, administrative support for an integrated program is absolutely essential. Venville and Wallace (1998) found that in schools where integration had successfully taken place, the entire school philosophy had embraced the idea of integration. If a commitment to the premise of integration is not present, it will be far too challenging for a teacher in a high school setting to overcome the many obstacles that are present in the course of planning and implementing such a program. Many of the elements for success are built into the structure of the school, such as room allocation, timetable planning, resource allocation, and communication with feeder schools and home.

### *Implications for Theory*

Much of the discussion about integrated science and mathematics revolves around the need for a clear definition of integration. The desire for a singular definition for integration stems from the need to compare research meaningfully. How can you know if an integrated science and mathematics curriculum is having a significant impact on achievement and attitude if there are as many variations of integration as there are classrooms and teachers where integration is happening? This explains the search for a theoretical framework within which integration can be defined and somehow placed on a scale that will allow it to be sorted and classified. This is a completely understandable and reasonable approach for the researcher to take.

Drake (1998) states that integrated curriculum must necessarily exist on a continuum based on the amount of connection made between two subjects. In fact, that continuum is part of a larger continuum that places transdisciplinary education at the farthest point along the scale. At that point, the disciplines serve only as vehicles used to reach answers and understanding of big questions and broad ideas. In her review of the literature, Drake found that any type of integration benefits students. Thus, the definition for integration is viewed by Drake as a flexible and accommodating idea. For every context and classroom, there is a form of integration that will work.

Thus, the search for a definition of integration, while interesting, is secondary to the practical demands of integration within the context of a real classroom. Real classrooms consist of very different groups of individuals who are themselves changing and transforming as a school year progresses. Teachers must respond to these differences period to period, day to day, and year to year. To expect any one model of integration to



work consistently well with all groups of students would require an educator to ignore this basic truth of teaching. Such an expectation could actually be dangerous to the successful implementation of an integrated program. If attempts are made to pigeonhole a program as being a certain approach to integration, it may prevent or hide opportunities for integration that do not quite fit with the framework that a particular definition provides. It may prevent approaches that better fit the needs of a particular group of students or take advantage of unique opportunities or talents of available personnel. It may limit even small attempts to provide integration in science and mathematics classrooms; some may assume that if their approach does not fit the prescribed definition, it is not worth doing. In effect, a definition, rather than promoting a new understanding of integration, would instead stifle it.

A better way to approach this is to provide educators with a view of the broad range of possibilities that integration provides. There may be some approaches that fit better with the teaching style of a given teacher. Perhaps the curricula will allow for integration based on the common methods of investigation between science and mathematics, as suggested by the Berlin-White Integrated Science and Mathematics Model (1994). Maybe the structure and organization of a given school lend themselves to the idea of parallel instruction as defined by Hurley (2001). With a full and rich repertoire of integration strategies available, educators will be more likely to find one that works in their unique situations.

Rather than a definition that attempts to state what integration is, perhaps it is better to define the practices within integration that seem to have the most significant impact. If the desired outcomes of effective integration are improved achievement in

science and mathematics and an improved attitude towards both subjects, how can learning be organized to ensure these outcomes occur? In all of the diverse integrated classrooms that have seen positive results, operating under different and sometimes quite opposite definitions of integration, what common elements of pedagogy exist? The fact that science and mathematics existed together in a program is secondary to the question of how that mutually beneficial existence was nurtured and encouraged to flourish.

### *Implications for Further Research*

The researcher had hoped initially that the results of this work would provide some answers to a long-considered question regarding the effects of integrated programming on student attitudes and achievement in science and mathematics. To a small degree it did this, but it also highlighted just how many more questions remain to be answered before a clear understanding of integration could emerge.

The first consideration for further research would be the long-term impact that the integrated program may have on the treatment group as compared to the control group. Some differences existed between the treatment and control groups in their achievement in math and science, but it is not known if that achievement influences student performance beyond the grade 9 experience. It would be interesting to look at achievement in grade 10 science and mathematics to see if any differences exist between the control and treatment groups. Perhaps the understanding that the integrated students had was deeper, becoming more evident after a period of time has passed. Perhaps it is not only the quantity of the understanding that needs to be measured, but also the depth and longevity.

Student decisions could be monitored to see whether attitudes of students in the treatment group toward science and mathematics are affected over a longer period of time. Although attitudinal surveys did not suggest differences in attitude between the program and control groups, time may serve to bring attitudinal changes into a sharper focus. If the students were tracked through their high school careers, it would be possible to determine if the integrated experience has an impact on senior science and mathematics course selections. Similarly, applications to university and college would inform us as to the actual career intentions of these students. Such important decisions made by students would provide a greater and more authentic insight into the attitudes of the students than a survey can provide.

Parental attitude and opinion were not considered in this research and may have provided some interesting perspectives with respect to the results. It would be beneficial to know how the parents viewed the impact of the program on their sons or daughters and what advantages or disadvantages they perceive their children are experiencing as a result of their participation in the integrated program. In addition, some insight into the parents' rationale for participation would be valuable. Parents may have had a particular agenda when they opted to allow their children to participate in the program. This agenda may provide insight into the nature of students that opt to participate in an integrated program.

Since only one teacher taught the integrated course to the treatment group, it is possible that any differences detected were related to teacher effects rather than the instructional strategies used. The second year of the program has involved a second teacher who, while following the basic format of the program, is nonetheless injecting her own style and developing her own approach to integrated instruction. As the course

continues into its third year, it would be important to determine whether the achievement and attitudes of the students yield the same results with two teachers as when a single teacher was involved.

The decision to extend the program to grade 10 science and mathematics has not been made, nor is it presently under official consideration. Should such a program be developed it would allow research into several aspects of integration. First, did participation in the grade 9 program predict greater success in the grade 10 program? It stands to reason that a student who has effectively “practiced” their integrated science and mathematics skills for a year might be more successful than a student who is new to the format of an integrated classroom. One year of integration may not be sufficient to develop the habits of mind and deeper understandings that are hoped for from an integrated experience. Sustained exposure to integration might provide better achievement and greater attitudinal changes than a single year can provide.

It is possible that it was the full-year structure, and not necessarily the integration, that was beneficial to students in the treatment group. It would be reasonable within the parameters of the school to offer a double period every day of science and mathematics for one semester rather than one period all year long. Eliminating this difference between the treatment and control group would help eliminate one variable that may have played a role in the results. In Hurley’s (2001) review of the evidence for integration, the most frequent duration of integration in the literature was one full school year. While the assumption has been that the full year allowed for greater time and opportunity for learning to take place, it is possible that a single semester of highly focused and intensive science and mathematics instruction would be more effective.

## Conclusion

Students today live in a culture that provides information from a myriad of sources in a vast, interconnected network. Their experiences in school, however, still suggest that information and ideas can be considered in discrete, neatly packaged categories. Integration of science and mathematics allows the school experience to better reflect the authentic interconnectedness of the two subjects.

The focus of the development of the integrated program and this research was primarily about optimizing student success. Although the research did not provide any absolute answers about the value of integrated science and mathematics program to this end, it did provide some tantalizing glimpses of the potential it offers. Although the measures of success were not as dramatic and numerous as had been hoped, there were nonetheless signs that the integrated program did have a positive impact. The experiences of the inaugural year will allow improvements to be made to the program that may, in turn, result in further improvements to student learning and attitude. The concept of student attitude is one that is not often measured and considered to be a marker of success during a school year. Singh et al. (2002) found that motivation and attitude had a significant effect on academic achievement in science and mathematics. Given the connection to achievement, perhaps it should be considered as an important aspect to consider more carefully.

The research provides an impetus for further changes to assessment and evaluation practice. If differences in learning did not register with the traditional instruments used to measure student achievement, then perhaps these instruments are not

measuring learning as accurately as was previously thought or are not measuring the learning that we actually value. Yager (2000) identifies the fact that testing in the traditional manner is a poor method for use in determining whether an individual has actually learned something. Yager goes on to suggest that in order to be engaged in their learning, the goal should not be the completion of a test but rather the creation of an original product and the formulation of expertise. Useful action resulting from learning is desirable, along with the sense that the consequences of learning cannot be fully predicted. Such a realization demands reflection on what it means to know and understand something in our very complex, interconnected, information-saturated society and how we want and expect students to express that understanding.

Integration remains a strategy with enormous potential and value to the science and mathematics classroom. The elusive promise that integration holds stubbornly remains, even when research has not provided the compelling and overwhelming evidence to support it. Integration is based in sound philosophy, and teachers recognize the inherent value and benefit to students of connecting science and mathematics in the classroom. The fact that research has not yet been able to demonstrate all of the benefits of integration does not mean that they do not exist. It does mean that the best strategies and models for integration have yet to be determined. It also means that the measures of success being used are not capturing the true value of integration. Further research is needed to ensure that the educational potential of integrating science and mathematics is successfully realized. The impact of effectively integrating science and mathematics will most certainly make it worth the effort.

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## Appendix A

### Science Attitude Survey

***Please read each statement and indicate your answer by putting a checkmark in the appropriate box.***

1. a) When you are finished school someday, do you expect to work in a field that requires education in math?

☐ Yes

☐ No

Please answer the following questions by putting a checkmark in the appropriate box:			
1. b) How important do you think it is to do well in science?	Not Important <input type="checkbox"/>	Important <input type="checkbox"/>	Very Important <input type="checkbox"/>
2. How important do your parents think it is for you to do well in science?	Not Important <input type="checkbox"/>	Important <input type="checkbox"/>	Very Important <input type="checkbox"/>
3. How important do your teachers think it is for you to do well in science?	Not Important <input type="checkbox"/>	Important <input type="checkbox"/>	Very Important <input type="checkbox"/>
4. Science is an important school subject.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
5. Many good jobs require the study of science.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
6. Science is more difficult than other school subjects.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
7. If I were faced with a difficult problem in science, I would likely keep trying until I solved the problem.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
8. To do well in science you need natural ability.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
9. When I get an unusually low mark in a science class, it is most likely because the course was not well taught.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
10. When I get an unusually high mark in a science class, it is most likely because of good luck.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
11. How do you feel about the statement "I am usually bored in science class"?	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
12. How do you feel about the statement "I feel good about science"?	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
13. How do you feel about the statement "I am genuinely interested in science"?	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>

*Adapted from Council of Ministers of Education, 1999*

## Appendix B

### Math Attitude Survey

***Please read each statement and indicate your answer by putting a checkmark in the appropriate box.***

1. a) When you are finished school someday, do you expect to work in a field that requires education in math?

☐ Yes

☐ No

Please answer the following questions by putting a checkmark in the appropriate box:			
1. b) How important do you think it is to do well in math?	Not Important <input type="checkbox"/>	Important <input type="checkbox"/>	Very Important <input type="checkbox"/>
2. How important do your parents think it is for you to do well in math?	Not Important <input type="checkbox"/>	Important <input type="checkbox"/>	Very Important <input type="checkbox"/>
3. How important do your teachers think it is for you to do well in math?	Not Important <input type="checkbox"/>	Important <input type="checkbox"/>	Very Important <input type="checkbox"/>
4. Math is an important school subject.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
5. Many good jobs require the study of math.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
6. Math is more difficult than other school subjects.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
7. If I were faced with a difficult problem in math, I would likely keep trying until I solved the problem.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
8. To do well in math you need natural ability.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
9. When I get an unusually low mark in a math class, it is most likely because the course was not well taught.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
10. When I get an unusually high mark in a math class, it is most likely because of good luck.	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
11. How do you feel about the statement "I am usually bored in math class"?	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
12. How do you feel about the statement "I feel good about math"?	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>
13. How do you feel about the statement "I am genuinely interested in math"?	Disagree <input type="checkbox"/>	Agree <input type="checkbox"/>	Agree Strongly <input type="checkbox"/>

*Adapted from Council of Ministers of Education, 1999*

**Appendix C**  
**Brock Research Ethics Board Approval**



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## Brock University

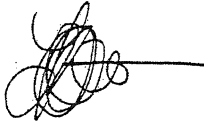
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Research Services  
reb@brocku.ca

St. Catharines, Ontario  
Canada L2S 3A1

Telephone (905) 688-5550 ext 3035  
fax (905) 688-1748

**DATE:** August 31, 2005

**FROM:** Linda Rose-Krasnor, Chair  
Research Ethics Board (REB) 

**TO:** Joe Engemann,  
Cindy COSENTINO

**FILE:** 05-021 COSENTINO

**TITLE:** Investigating the Impact of an Integrated Mathematics and Science Program on the Attitude and Success of Grade 9 Students

---

The Brock University Research Ethics Board has reviewed the above research proposal.

**DECISION:** Accepted as clarified.

This project has received ethics clearance for the period of August 31, 2005 to November 30, 2006 subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The clearance period may be extended upon request. *The study may now proceed.*

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and cleared by the REB. During the course of research no deviations from, or changes to, the protocol, recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must provide clearance for any modifications before they can be implemented. If you wish to modify your research project, please refer to <http://www.brocku.ca/researchservices/forms> to complete the appropriate form **Revision or Modification to an Ongoing Application**.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

The Tri-Council Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form *Continuing Review/Final Report* is required.

Please quote your REB file number on all future correspondence.

LRK/bb



**Appendix D**  
**Integrated Mathematics and Science Course Outline**

**CSI Unit for Grade 9 Integrated Math/Science**

<b>Topics</b>	<b>Learning/Literacy Strategy</b>	<b>Journal</b>
Course introductions Journals Multiple Intelligences Learning Styles Community Agreements Science and Math Portfolio	~People Hunt (from Tribes) ~Multiple Intelligence Survey ~Learning Styles ~use sticky notes with partner write answers to the following question: <i>What behaviours from teachers and other students help you to feel comfortable in a classroom and help you to learn?</i> <i>(Post stickies on board. Do gallery walk. Classify and categorize them as a class. Write community agreements based on those categories)</i>	<i>Think of a time you learned something really well. What did you learn? Why do you think you learned it so well? Who taught you?</i>  <i>Compare MI surveys with elbow partner. How are you the same? How are you different? How do you think you will best work together?</i>
Inquiry Model in Math and Science Collecting Data Analysing Data Making a Conclusion Quantitative & Qualitative data	~Think Pair Share: How Does this class Learn Best? ~Use Inquiry organizer to come up with ideas as to how this question could be answered ~Use manipulatives to collect and record information about learning styles	
<b>CRIME SCENE</b> (Scenario set up in room to give the impression that the class mascot, a giant stuffed Pikachu, has met an unfortunate demise at the hands of an unknown assailant) Class begins with distraught teacher explaining what has happened and what she knows. Students are encouraged to take notes	~in pairs brainstorm all the qualitative and quantitative data that could be collected from the crime scene ~share ideas with table groups (4) ~using tools available and without touching the evidence, collect all the information you can from the crime scene	

Coordinate Plane Scatterplots		<i>From what you learned about scatterplots today, can you think of how you might use them to find out something about who committed the crime and how &amp; when the crime occurred? (Allow sharing of ideas with partner after sufficient time to think &amp; write)</i>
<p>Inquiry Model: Asking Good Questions  <i>(What good questions can we ask about the crime that occurred? What questions could we ask that scatterplots would help us answer?)</i></p> <p>Conducting an inquiry and analyzing results          Possibilities include:  <i>Nose tip height vs. height</i>  <i>Stride length vs. height</i>  <i>Shoe length vs. foot size</i>  <i>Foot size vs. height</i>          Making a conclusion          Measures of Central Tendency</p>	<p>~Use inquiry organizer to plan out an investigation with partner.          ~Homework: Collect data at home tonight from people not in the age range of our class. Discuss why this is a good idea.          ~Share conclusions with other groups/record conclusions from other groups          ~manipulate and analyse class data to further refine conclusions</p>	<p><i>From all the data that has been collected and all the conclusions you have heard, which data do you think is the most reliable? Why do you think so?          How tall do you conclude the murderer is based on all the information you have?</i></p>
<p>Inquiry: Using data to determine the time of the crime          Writing a Method          Integers</p>	<p>~inquiry organizer to plan; conduct inquiry with partner; analyze results independently          ~Peanut Butter and jam Sandwich demo-(write instructions on how to make a PB &amp;J sandwich, and then read to another group and have them follow exactly what is said. Could be done as a</p>	<p><i>Thinking back to the crime scene, what data do you have that could help you estimate the time of the crime?</i></p>

	<p>teacher demo if you have nut allergies in class)</p> <p>~Class discussion as to what makes a good method and why precision is important when a scientist writes a method</p>	
<p>Using a Motion Detector</p> <p>Distance-Time Graphs</p> <p>Analysing D-T graphs</p> <p><i>(practice together, then assign data from crime scene as individual work)</i></p>	<p>~in 3's use CBR to explore how various movements affect the appearance of D-T graph</p>	<p><i>How might data from a motion detector be useful in analyzing a crime scene?</i></p> <p><i>What would the limitations of this information be?</i></p>
<p>Review qualitative &amp; quantitative observations</p> <p>Physical Properties</p> <p>Microscope work-using a microscope to examine fibre samples to determine their origin</p>	<p>Paraphrase passport</p> <p><i>(students read the textbook definition of a particular physical property to their partner. The partner then restates the description in their own words. The textbook is closed while the paraphrased definition is written on the organizer; limit of 20 words or less!)</i></p>	<p><i>Explain the difference between qualitative and quantitative observations</i></p> <p><i>What qualitative observations can you make using your 5 senses?</i></p>
Chemical properties	<p>~Tell Me Why</p> <p><i>In pairs students examine a variety of pictures. As a pair, they must agree whether the picture is showing a physical change or chemical change or both. They must record the specific reason for their choice</i></p>	
Lab: Observing Changes 1.8	<p>~Comic Strip</p> <p><i>Read lab over. Make a comic strip that shows exactly what you must do in this lab. Share with partner and peer assess: is anything missing? Could you follow the comic strip and know exactly what to do?</i></p>	
Using chemical and physical properties to determine the identity of the unknown powder	<p>~Comic strip</p> <p><i>Make a comic strip to demonstrate how you will do this lab. Use this to write your</i></p>	<p><i>We found an unknown white powder at the crime scene. How could</i></p>

Writing a conclusion; justifying your conclusion	<i>method.</i>	<i>we figure out what that powder was?</i>
DNA-introduction	<p><i>Question: Could the evidence in the picture be used to identify someone who committed a crime? Would you be 100% sure of the guilty persons' identity?</i></p> <p><i>~in elbow pairs examine a set of pictures considering the above question. Then trade pictures with your table group and go through those the same way. Get into table group and discuss each picture as a group of 4.</i></p> <p><i>~Lettered Heads-each member of the group takes a letter A, B, C, D and will represent the group if chosen during the class discussion</i></p> <p><i>~Concept map: DNA</i></p> <p><i>In groups of 4 make a concept map of what they know or think they know about DNA</i></p>	<p><i>What is a "perfect crime"?</i></p> <p><i>Is it possible to commit a perfect crime? Explain your thinking.</i></p>
<p>DNA-what is it? What does it do?</p> <p>Using DNA to solve a crime</p> <p><i>(CBC News in Review: DNA Evidence: Science and Justice)</i></p> <p>DNA fingerprinting</p>	<p><i>~Reading:</i></p> <p><i>Most Important/Least important</i></p> <p><i>~Analyzing DNA</i></p> <p><i>Fingerprinting</i></p>	<p><i>Do you think someone becomes a criminal because of their DNA, or because of how they are raised?</i></p> <p><i>Do the notes Mrs. Cosentino received give you any clues about who might have committed the crime and their motive?</i></p> <p><i>If we could get DNA samples from the most likely suspects, who would they be?</i></p>
<p>Cell Theory</p> <p>Writing a Hypothesis</p> <p>Structure/Function of</p>	<p><i>~Hypothesis: The Case of the Rotting Food (work in pairs)</i></p> <p><i>~Setting a context: article:</i></p>	<i>What major mistake did the man in the article make and</i>

parts of a Cell	<i>Dead People Do Tell Tales</i> <i>Reading &amp; discussion</i>	<i>how does this relate to cell theory?</i>
Mitosis Why cells divide Scientific drawings Microscopes Identifying stages of mitosis	~build a kinesthetic model of mitosis and demonstrate to another group. Have group assess the model for accuracy. ~microviewer activity ~Onion root tip	
Cell Division Reproduction Binary fission Using cells to solve crimes-relationships Interpreting and Analysing 2-variable data First differences	~model a bacterial colony growing; create a graphical model of growth ~analyze growth data to determine time of crime	